CONTENTS

PAGE

THE SPERMATOGENESIS OF *Locustana Pardalina* (WALKER) (THE BROWN TREK LOCUST). By D. J. MALAN, M.Sc., and D. E. MALAN, M.A., Ph.D. (With Plates I, II, and one Text-figure) . . . 1

NOTE ON THE EXPLICIT (NON-SYMBOLIC) EXPRESSION OF CONCOMITANTS OF BINARY QUANTICS. By A. W. VEATER. (Formerly Scholar of Trinity College, Cambridge. Instructor Commander, R.N. (retired).) 23

Gundlachia AT MALVERN, AND AN EXAMINATION OF THE RADULAE OF OTHER INTERMEDIATE HOSTS OF THE TREMATODE PARASITIC WORMS IN NATAL. By F. G. CAWSTON, M.D. Cantab. (With Plates III and IV). 39

NOTE ON THE SUM OF THE SIGNED PRIMARY MINORS OF A PERSYMMETRIC CONTINUANT. By Sir THOMAS MUIR, F.R.S.. . . . 43

CONTRIBUTIONS TO OUR KNOWLEDGE OF THE FRESHWATER ALGAE OF AFRICA. 6. *Some Freshwater Algae from Stellenbosch, Cape of Good Hope.* By W. J. HODGETTS, D.Sc. Communicated by Miss E. L. STEPHENS. (With 16 figures in the Text) . . 49

NOTE ON A BURIAL-STONE. By S. H. HAUGHTON, B.A., D.Sc., F.G.S. (With Plate V) 105

NOTES ON THE HABITS AND LIFE-HISTORIES OF CERTAIN LITTLE-KNOWN ANURA, WITH DESCRIPTIONS OF THE TADPOLES. By J. H. POWER. (With Plates VI–IX and five Text-figures) . 107

REPORT ON A COLLECTION OF CRUSTACEA FROM PORTUGUESE EAST AFRICA. By K. H. BARNARD, D.Sc., F.L.S., F.R.S.S.Afr. (Published by permission of the Trustees of the South African Museum.) (With Plates X–XI) 119

COLOUR AND CHEMICAL CONSTITUTION. PART XX.—SOME RESIDUAL PROBLEMS. By JAMES MOIR.. 131

SOME ADDITIONS TO THE KNOWLEDGE OF *Procolophon*, *Lystrosaurus*, *Noteosuchus*, and *Cistecephalus*. By F. VON HUENE, Tübingen. (Communicated by Dr. S. H. HAUGHTON.) (With seven Figures) 139

NEW AND NOTEWORTHY SOUTH AFRICAN CHAROPHYTA. I. By JAMES GROVES and EDITH L. STEPHENS. (With Plates XII–XV) 145

PAGE

On some new Mollusca from Tertiary Beds in the West of the Cape Province. By S. H. Haughton, B.A., D.Sc. (Published by permission of the Hon. the Minister for Mines and Industries.) (With Plates XVI–XVIII) 159

The Breeding Habits and Life-Histories of some of the Transvaal Amphibia. By Vincent A. Wager, B.Sc. (With eight Text-figures). 163

On the Anatomy of some Shrubby Iridaceae. By R. S. Adamson. (From the Botanical Department, University of Cape Town.) (With Plate XIX and nine Text-figures) 175

An Extension of Ceva's Theorem to Polygons of any Number of Sides. By Alexander Brown 197

A Statistical Inquiry into the Population Problem in South Africa. By Alex. Roberts. (With one Chart) 201

The Hydrolytic Properties of certain Amino-Acids. By Louis Pierre Bosman 245

The Preparation of Umbelliferone. By Ernest George, B.A., M.Sc., A.I.C. (Communicated by Dr. J. Moir) 255

Some Phthalein Analogues. By Ernest George, B.A., M.Sc., A.I.C. 259

Note on Decrease in Acidity during Ripening of Grapes. By P. R. v.d. R. Copeman, B.A., B.Sc. (With two Text-figures) . 269

Note on the South African Marine Mussel *Mytilus meridionalis* Krauss (1848). By D. B. Swart. (Communicated by Dr. C. von Bonde.) (With three figures in the Text). 275

Three New Helminths. By H. O. Monnig, B.A., Ph.D. (With twelve Text-figures) 291

Hadamard's Approximation-Theorem since 1900. By Sir Thomas Muir 299

A New Sundew, *Drosera regia* (Stephens), from the Cape Peninsula. By Edith L. Stephens. (With Plate XX, and one Text-figure) 309

On some Strongylid Nematodes of the African Elephant. By H. O. Monnig, B.A., Ph.D. (With seventeen Text-figures) . 313

Glycolysis in Blood. By Arthur Dighton Stammers . . 323

On the Pressure of α-Hydroxy Acids in Blood. By Arthur Dighton Stammers 337

Some Observations on certain Pathological Changes resulting from Inanition. By Arthur Dighton Stammers. (With three Text-figures). 341

Minutes of Proceedings, 1924–1925 . . . . . i–xxxvii

List of Officers, Fellows, and Members, 1925 . . xxxix–xlvii

TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XIII.

THE SPERMATOGENESIS OF *LOCUSTANA PARDALINA* (WALKER) (THE BROWN TREK LOCUST).

By D. J. Malan, M.Sc., and D. E. Malan, M.A., Ph.D.

(With Plates I, II, and one Text-figure.)

Introduction.

The following work was carried out in the Zoological Department of the Transvaal University College, Pretoria, during 1922–23. At this time Professor J. C. Faure was busy investigating the life-history of *Locustana pardalina* (Walker), the Brown Trek Locust. This animal occurs in two phases, swarm and solitary, and it was thought that a close cytological examination of these forms might, in addition to its inherent interest, throw some light upon the origin of the phases. Unfortunately, no palpable results have been attained in this direction. The writers trust, however, that the results which were obtained with regard to the purely cytological aspects of gametogenesis in this animal, serving as they do to check to some extent the results of other investigators in insect cytology, are of sufficient interest in themselves.

It is felt that this account of the spermatogenesis of the Locust is by no means complete, especially the part dealing with spermiogenesis. Despite its numerous shortcomings, however, all the important aspects have been touched upon, and in cases where difficulties were encountered and hence no positive results or conclusions formulated, likely suggestions were advanced.

The authors wish further to express their sincere gratitude to Professor J. C. Faure, who most generously placed his breeding material at their disposal.

Glossary.

Cytology, being a comparatively modern development of science, is suffering from the lack of a well-standardised terminology. The same structure is often known by several names, each author inventing a new term for the same thing. On the other hand, the same term is often applied to different structures. This leads to inevitable confusion, and, for the sake of clearness, the following glossary is attached, modified after Gatenby, Agar, Bowen, and others. The older well-established terms are not given.

Nebenkern : the prominent mitochondrial body in the insect spermatid. The term " macromitosome " has been proposed for this structure (Gatenby), on account of the fact that " nebenkern " has erroneously been applied to denote the various following structures :—

1. The chondrioplasts and archoplasm of Pulmonates and other molluscs.
2. The secondary nuclei in *Camponotus* (an ant).
3. The secondary nuclear body in *Paramoeba eilhardi* (Schaudinn).
4. The micronucleus of some Ciliates (Butschli and Hertwig).

It may be pointed out that the proposed term, macromitosome, is rather unfortunate, as it conveys the idea of a mitosomal body, that is, a body formed from or having some connection with the spindle remnant.

Mitochondria : are granular or rod-like bodies found in the cytoplasm of germ-, nerve-, gland-, blood-, muscle-, and connective-tissue cells of all animals. According to Gatenby, they are dissolved by acetic acid, alcohol, chloroform, and ether, resist dilute nitric acid (about 3 per cent.), are sometimes turned brown (rarely black) by osmic acid, are preserved by chromium salts, osmic acid, and formalin, and stain *intra vitam* with janus green, neutral red, etc.

Chondriokonts, Chondriosomes : are synonyms for mitochondrial bodies.

Archoplasm : the dense protoplasmic mass found round the centriole.

Idiosome : a term introduced in 1896 by Meves to denote " die spezifisch beschaffene Huelle, welche die Centralkoerper in den maennlichen Samenzellen umgiebt." Gatenby alleges that it is the same as archoplasm.

Chondrioplasts : the rodlets or batonettes found in germ-cells of animals studded round the periphery of the archoplasm. These rodlets are akin to the mitochondrial bodies in fixing and staining affinities, and are evidently homologous with the Golgi rods (Gatenby). Apparently the latter term is used when these bodies are not merely confined to the archoplasm, but are spread out in the cytoplasm.

Acroblast : any body (or bodies) found in the cytoplasm of the male germ-cells, which finally gives rise to the acrosome or perforatorium (Gatenby).

Spermiogenesis (Bowen), *Spermateleosis* (Gatenby): the metamorphosis of the spermatid into the spermatozoon.

Synizesis: the contraction of the chromatin threads taking place in the prophases of the primary spermatocytes, resulting in a dense chromatic mass occupying a certain portion of the nucleus, with the rest of the nucleus clear.

Syndesis: the conjugation of homologous chromosome threads. This phenomenon very often takes place during synizesis, and is consequently obscured.

Diakinesis: may almost be defined as the very late diplotene stage. During diakinesis the chromatic threads of the previous stages have already contracted to such an extent that they now appear as irregular masses, often in peculiar formations of O's and crosses.

Technique.

After experimenting extensively with Locusts in their various stages, it was found that those in the fifth moult, the one before the complete adult stage, answered most satisfactorily. The testes of those in earlier stages were filled with spermatogonia, whilst the testes of adult forms were too mature, some containing hardly any cells and others comparatively few. The testes of Locusts in their fifth moult contained spermatogonia, spermatocytes, spermatids, and often fairly mature sperms, in fact, all the required stages.

During the first twelve months of the investigation sections were prepared by the usual fixing and staining methods; such fixatives as carnoy, petrunkewitsch, bouin, etc., were used, and the staining was carried out with Heidenheim's iron-haematoxylin with or without eosin or acid fuchsin as counter-stains. Haemalum was also used very successfully, but iron-haematoxylin gives a sharper chromatic stain. It was found that reducing in picric acid after iron-haematoxylin, instead of in ferric alum, gave very good results, but the latter process is quicker. These methods are admirable for a study of the nuclear contents in germ-cells, in addition to which the centriole and axial-filament usually show well. The nebenkern and the spindle bridge are sometimes seen in these preparations.

As far as the cytoplasmic inclusions are concerned, these methods are practically useless, and consequently a new series of preparations had to be made in which methods such as outlined by Gatenby and Bowen were employed. Unfortunately these new methods yielded results which were by no means very satisfactory. It appears that a technique which is perfect for a particular animal or group of animals does not necessarily give the best results when applied to other animals, but needs minor modifications,

such as, for example, longer fixation, etc., before the best results can be obtained.

A brief account of the methods used for the cytoplasmic inclusions may be given here. As fixatives the following were used: strong Flemming, Flemming with only a few drops of acetic acid, Flemming-without-acetic-acid (F.W.A.), Champy, Regaud, formalin (10 per cent.), primary fixation in formalin plus secondary fixation in osmic acid, Mann's corrosive osmic, primary fixation in Mann's plus secondary fixation in osmic acid.

It will be noticed that all these fixatives, with the exception of Flemming, lack acetic acid, and that they all lack alcohol, chloroform, etc., the ordinary ingredients of the common fixatives. On the other hand, most of them contain osmic acid. Gatenby contends that, in order to preserve cytoplasmic inclusions, it is absolutely essential to use such fixatives, as the acetic acid, alcohol, chloroform, ether, etc., dissolve these structures. He has obtained his best results with F.W.A. and Champy. It might be stated, however, that the mitochondria, after condensation to form the spermatid nebenkern, seem fairly resistant to acetic acid, and show comparatively well in numerous acetic preparations. But, as has been said, a technique which may be perfect for a certain group does not always have the same effect on another. For example, Bowen, working on the Hemiptera, got good mitochondrial results with Flemming fixation, and one gathers that he could not see the necessity of Gatenby's insistence on using non-acetic fixatives; but when he investigated the Lepidoptera, on which group Gatenby had been working, he found that such fixatives were absolutely essential.

Undoubtedly, however, the mitochondria in the form of the spermatid nebenkern resist the action of acetic acid to a large extent, and apparently only become dissolved after prolonged exposure to such a fixative. Not only in our own acetic preparations does the nebenkern often show, but also in some acetic preparations of Lepidoptera have we had occasion to see it quite distinctly, and this holds good also for the Hemiptera. This fact is further borne out if one considers that cytologists had for a long time already been acquainted with the nebenkern, even before its derivation from the mitochondrial bodies was known or modern cytological methods employed. The reason for this, no doubt, is due to the fact that the nebenkern is an exceedingly concentrated structure, having been formed by the condensation of numerous mitochondrial bodies, and, as such, would resist the dissolving action of acetic acid for a much longer period than the individual mitochondria.

Generally, with these non-acetic fixatives the fixation is very capricious and usually poor, success being largely a matter of luck. It was found that after osmic fixation acid fuchsin and light green answered best as counter-stains, whereas eosin counter-stains very faintly and orange green not at all.

The Spermatogonia.

These cells can easily be distinguished from the spermatocytes by the following characteristics :—

1. Their position—they are always located in the distal parts of the testicular tubules, *i.e.* the part farthest away from the vas deferens.

2. Their size—there is quite a striking difference in size between the spermatogonia and the spermatocytes, the former being much smaller than the latter.

3. The condition of the chromatin in the respective nuclei. The threaded stages, so characteristic of the nuclei of the spermatocytes, are never found in the spermatogonial nuclei, and during mitosis the chromosomes found in the latter are totally different in shape from those of the spermatocytes (*cf.* figs. 1 and 13*a*).

Sometimes it is somewhat difficult to interpret with certainty to which category a particular cyst or cysts of germ-cells belong, if one were to apply only one of the above three characteristics. When all three of the above characteristics are applied for identification, a correct interpretation can invariably be given. This is possible in longitudinal sections of a testis, where the tubules are laid open in length. In a transverse or oblique section it is of course sometimes impossible to say whether such a section has been taken through the proximal, middle, or distal portion of the testis, and then only the last one or two characteristics must serve for identification. Anyone, however, slightly familiar with the structure of germ-cells, will not experience much difficulty in this respect.

The proportion of the length of a tubule occupied by spermatogonia depends, of course, upon the age of the testis. In old animals only a few spermatogonial cysts may be found at the distal extremity of the tubule, whereas in young forms the greater part of the tubule may be filled with these cells. It has also been noticed that the epithelium investing the distal extremity of a tubule is much thicker than the epithelium lower down, due to the fact that it is in this zone that the germ-cells are generated.

As is well known, the spermatogonial phase in the germ-cycle is the multiplicative phase. By a method to be explained later, it was found that the number of mitotic divisions in the spermatogonial phase was seven. In other words, each primary spermatogonium eventually gives rise to 128 primary spermatocytes, and, since there are still two spermatocyte divisions to follow, the ultimate result will be that 512 spermatozoa are formed from each primary spermatogonium originally budded off from the germinal epithelium.

The diploid number of chromosomes found in a spermatogonial equatorial plate is 23, of which 22 are autosomes and 1 is the X-chromosome

(fig. 1). These chromosomes differ very much in shape and size from those found in the first maturation division plates, being much longer and not so compact. Further, there is a strong tendency for the homologous chromosomes to lie in pairs. It may be added that, owing to the large size and number of the chromosomes, a perfect spermatogonial plate, showing all the 23 chromosomes in one section, is only rarely to be found.

The spermatogonial division is equational, each daughter-cell again receiving the double complement of chromosomes. During the anaphase each long chromosome has the form of a V, the apex of the V being probably that point by which the chromosome is attached to the fibre. Soon after division the chromosomes in the daughter-cells form confused masses, which give rise to a rough reticulate structure (fig. 2). This rough, plotch-like condition of the nucleus is very typical of the resting spermatogonia. The number of these irregular plotches of chromatin could never be ascertained, but probably corresponds to the diploid number of chromosomes.

In preparation for the next division, these masses of chromatin gradually contract, becoming more distinct and staining more intensely. They soon assume the definite shape of chromosomes, which are at first very long rods (fig. 3). These, after further contraction, eventually give rise to the typical spermatogonial chromosomes, which become arranged in an equatorial plate (fig. 1). Of the 22 autosomes, 6 could be distinguished by their smaller size.

The X-chromosome behaves quite normally throughout the spermatogonial phase and cannot be identified with certainty. After the seventh multiplicative division the nucleus of the daughter-cell becomes reconstructed into a typical reticulum, this time devoid of a rough, plotch-like structure. This will be known as the Growth Phase proper, and the cell is now called a primary spermatocyte (fig. 4). It must be noted, however, that the growth of the spermatocyte does not only take place in this reticulate condition, but also throughout the greater portion of the Leptotene and Pachytene Phases.

Sequence of Stages from Growing Phase to Diakinesis.

The growing cells, when once identified as such, are easily distinguished by the condition of the chromatin in the nucleus (fig. 4). The nucleus is relatively large in comparison with the size of the cell and is characterised by its granular reticulum, which is comparatively faint and uniform. The plotch-like arrangement of the spermatogonial nucleus is absent, and no threads are as yet visible. These cells usually form a well-marked boundary between the spermatogonial cells situated in the distal portion of the testicular tubules on the one hand, and the threaded cells, *i.e.* the primary spermatocytes in the Leptotene and Pachytene Phases, situated more proximally.

On the proximal aspect of the growing cells other cells are found in which the nucleus appears full of extremely thin, delicate threads. These threads are distinctly single, and at first form a confused tangle with no regular arrangement whatsoever (fig. 5). Apparently, then, from the fine granular reticulum of the growing phase, the granules collect in linear series to form thin threads. Very soon the tangled arrangement is given up for a more regular one. The threads now become closely approximated towards one pole of the nucleus. This orientation of the thin threads towards one pole of the nucleus is not always easily recognised, but forms, on the whole, quite a typical arrangement. This is the Leptotene Phase (fig. 6). The X-chromosome takes no part in the formation of the threads, and usually occupies a position along the nuclear membrane, often near the orientation zone.

In the orientation of the leptotene threads some threads appear distinctly double in the orientation zone (fig. 6). This is due to syndesis or conjugation of the homologous chromosome threads taking place, which process is initiated where the threads all come together in the polarised zone. However, syndesis is greatly obscured by the fact that a marked contraction of the threads soon takes place. This is the Synizesis stage (fig. 7), and syndesis evidently goes on throughout this contraction phase, which is characterised by the fact that the chromatin contents of the nucleus are all aggregated into a comparatively dense mass, while the rest of the nucleus appears clear.

The dense contracted mass of chromatin gradually becomes disentangled again and the threads are now seen to be much thicker (Pachytene Phase, fig. 8). Soon the whole nucleus is again occupied by the pachytene threads, which at first also exhibit the polarised arrangement. After some time, however, the polarisation of the threads is given up and no definite arrangement can be made out. It is about this time that the threads exhibit a longitudinal split and thus the Diplotene Phase is attained (fig. 9). This split is presumed to be due to the fact that the homologous threads, which have conjugated during syndesis, now separate slightly, and Morgan considers that crossing over takes place at this stage (*cf.* Morgan's *Croonian Lecture*, 1922). At first the split is only very slight, but as the threads contract it becomes very distinct and, during the late Diplotene Phase, when contraction has already proceeded to a considerable extent, the split is very pronounced, and figures are seen which strongly support Morgan's theory (fig. 10). During these stages the contour of the threads is very irregular and the threads themselves are studded with chromatic granules.

About this time a secondary partial contraction takes place, in which the threads, now considerably shortened and thickened, cluster together, usually towards one side of the nucleus. The nucleus itself seems to

contract slightly. Owing to the close proximity of the threads at this phase, the staining capacity of the nucleus is very great (fig. 11), which, indeed, often appears as one uniform dark mass. The chromatic bodies gradually become disentangled out of this dark cluster and are soon found in peculiar irregular formations of crosses and O's, etc. This is the Diakinetic Phase or early Tetrad Formation (fig. 12). During diakinesis the nucleus appears quite clear and the X-chromosome, as in earlier stages, is a distinct and well-formed structure. The nuclear membrane still shows distinctly.

From now onwards the chromosomes begin to emerge gradually from the irregular chromatic masses, and by the time they have attained their distinct shapes the nuclear membrane is no longer visible.

The Maturation Divisions.

The irregular and peculiarly shaped figures of the Diakinetic Phase gradually become more compact and soon assume the definite shape of chromosomes. At first these are found scattered about in the germ-cells, but soon they become arranged definitely so as to form the equatorial plates of the first maturation division (fig. 13). It is at this stage where particular attention must be paid to the size and shape of the individual chromosomes, so that, if possible, the same chromosomes may be identified in other plates. This is an easy matter in forms possessing a few chromosomes, but becomes more difficult where a large number is involved, especially if there is not much size- or shape-difference to go by. In equatorial plates of the first maturation division showing all the chromosomes, three could always be distinguished by their small size, and these represent the six small ones of the spermatogonial plates. In addition, there are three huge ones, five medium ones, and the X-chromosome (fig. 13*a*).

As the chromosomes are now present in the haploid number, this is also the most convenient stage for counting them. Considerable difficulty was encountered here owing to the large size of the cells and the chromosomes, as well as the large number of chromosomes involved. With cells showing from six to twelve, and in exceptional cases thirteen chromosomes, it was impossible to decide upon the correct number. Thereupon various cells were traced singly through consecutive sections. By this means better results were obtained, which did not vary between such extreme limits as above, but which were nevertheless unsatisfactory, as there was not enough uniformity in the counts made. This was undoubtedly due to the fact that, owing to the radical change of field from one section to another, one could not identify with certainty the parts belonging to the same cell. Ultimately a certain cyst was followed up from the time it made its first appearance until it disappeared again. Each time a camera-lucida drawing was made

of the cyst, the cells contained in it, and the chromosomes within each cell. By thus studying each cell in relation to others all discrepancies were eliminated. It was found that the haploid number of chromosomes was twelve, of which eleven were bivalent autosomes and one was the univalent X-chromosome. Incidentally the following interesting facts were revealed :—

1. The cyst continued throughout sixteen consecutive sections, each of which was 6 μ in thickness, so that the length of the cyst must be approximately 96 μ.

2. Many cells made their appearance throughout three sections, and hence the diameter of the germ-cells must lie between the limits 12 μ to 18 μ.

3. The total number of cells in the cyst was 128.

This is probably the only satisfactory method to arrive at a reliable chromosome count in forms possessing large germ-cells and large chromosome numbers. In such cases it is exceptional to find complete equatorial plates, and very often it happens that plates which appear complete, prove on further inspection to be incomplete. Although there is considerable difference between consecutive fields, a minute study of the entire field with all its details enables one to interpret readily the changes encountered in going from one field to another. It is of course unnecessary to follow up an entire cyst in order merely to make a chromosome count, but it must be emphasised that a certain number of consecutive sections (about five or six) must be traced in which each cell is studied in relation to its neighbouring cells.

As was stated above, 128 cells were found in a cyst containing primary spermatocytes in the equatorial phase. We find that this number can be obtained only after seven divisions, so that the eighth division corresponds to the first maturation division and the ninth to the second maturation division, after which 512 spermatids will have been formed from each original spermatogonium. Whether the total number of divisions in the sperm cycle of all animals corresponds to this, cannot be asserted definitely, as practically no reference to this point is made in accounts of spermatogenesis. Indeed, as far as can be ascertained, the only other reference of this nature is made by one of us (D. E. M.) in connection with work on the Lepidoptera. He arrived at similar conclusions by counting the number of cut sections through a bundle of sperm tails. So that, at any rate for the Orthoptera and the Lepidoptera, the divisions, as specified above, take place, and seeing that, on the whole, there is such marked uniformity throughout the animal kingdom with regard to spermatogenetic phases, it is quite conceivable that approximately the above number of divisions takes place in many cases.

During Metaphase I, and even prior to it, the X-chromosome can usually

be identified by its early migration to the one pole (fig. 14). This is probably due to the fact that the bivalent autosomes, before being able to migrate, must first resolve themselves into the univalent elements, whereas the X-chromosome is ready for migration immediately after the plate arrangement has been attained.

The first maturation division is reductional for all the chromosomes, giving rise to secondary spermatocytes, half of which contain eleven univalent autosomes and half eleven univalent autosomes plus an X-chromosome. There is no reconstruction of the nucleus after the first maturation division. Almost immediately after the daughter-chromosomes have reached the poles they again become arranged into equatorial plates in preparation for the second maturation division (figs. 15, 16). Metaphase II is illustrated in fig. 17. The secondary spermatocytes can be distinguished readily from the primary spermatocytes by the much smaller size of the cells as well as of the chromosomes (*cf.* figs. 13*b* and 15). There is no abnormal behaviour of the X-chromosome in the second maturation division, which is equational for all the chromosomes, so that half the young resulting spermatids contain an X-chromosome (*i.e.* twelve chromosomes in all) and are consequently female-producing (fig. 15), whilst half are without it and are male-producing (fig. 16).

Spermiogenesis.

Comparatively soon after the second maturation division the young spermatid appears as shown in figs. 18, 19, 20. The nucleus is round and the chromosomes, arranged chiefly against the nuclear membrane, are fast losing their regular shape and are seen in various stages of dissolution (figs. 18, 19). The nebenkern is a prominent spherical structure about one-third the size of the nucleus. In some preparations it is much more pronounced than the nucleus, being affected to a greater extent by the stain. In such cases it appears simply as an intensely dark round body (fig. 20). In cases where the nebenkern is not so intensely stained it appears vacuolar and composed of numerous small vesicles (figs. 21, 22). It often shows as a darkly stained body with a ring of vesicles round its periphery (fig. 23), due to the fact that the chromophilic substance has become concentrated at the centre. The nebenkern usually touches the nuclear membrane, but sometimes a narrow space is found between the two. Often a granule is seen on one side of the nucleus either in the cytoplasm or on the nuclear membrane (figs. 20, 24). This is very likely the centriole. A few indistinct inclusions can often be made out in the cytoplasm, which represent Golgi bodies (fig. 20).

Occasionally at this stage a granule is seen on each side of the nucleus

(fig. 25). Three possible inferences may be drawn from this: (1) each lateral granule may be an acrosome; (2) each may be a centriole; (3) one may be a centriole and the other an acrosome.

With regard to the first inference, it may be pointed out that if both the lateral granules are acrosomes, the centriole must be so closely applied against the nuclear membrane that it is invisible, and, further, both acrosomes should show a tendency to move anteriorly towards each other, ultimately to fuse together to form the single apical acrosome. This latter phenomenon has never been observed, and consequently this inference must be discarded in favour of the other two.

Thus it is certain that one of the lateral granules in fig. 25 is a centriole, and whether the other is also a centriole or an acrosome will be discussed in due course. It may be mentioned here that an axial filament, proceeding from the centriole, has in no case been detected whilst the latter body occupies this lateral position, and no traces of idiosomic or archoplasmic material, attached to the Golgi bodies, can be discerned.

The next phase is where the centriole(s) has migrated to its permanent basal position and now lies between the nucleus and the nebenkern. It is rather peculiar that at this stage it is usually double, consisting of two minute granules (figs. 21, 22). The real significance of this double nature of the centriole is very difficult to interpret. The question arises, when did the centriole assume its double nature? This probably takes us back to the second maturation division. In Anaphase II a couple of cases were detected where there were two minute but distinct granules at the polar end of the spindle (fig. 26). Indeed, a number of cytologists have described the centriole as a double structure in the very young spermatid, but none take it as far back as Anaphase II. If it be borne in mind that the position of the (double) basal centriole is on the side of the nucleus, diametrically opposite to that occupied by the double polar centriole of Anaphase II, fig. 25 may be taken to represent a phase intermediate between the double condition of the centriole in Anaphase II and its double nature in the basal position. Hence fig. 25 may be explained as a stage reached during the migration of the two polar centrioles towards the nucleus and their divergence upon approximating the nuclear membrane, so that one passes along the one side of the nucleus and the other along the opposite, to the basal position. However, this procedure is only possible if it be assumed that the second inference is correct, namely, that both granules in fig. 25 are centrioles. Nevertheless the writers are of opinion that it is more probable that the third inference is correct, and that one granule in fig. 25 is the acrosome. This matter is brought up again under the heading "Discussion."

Whatever the origin of the double nature of the centriole may be, it is a structure quite frequently found in the young spermatid in the position

described above. Unfortunately in these cases the axial filament cannot be seen distinctly, but apparently it proceeds from one of these bodies only. A few cases are found in which there is only one small basal centriole. This may be accounted for in one of the following ways. Either the single lateral centriole, after having taken up its basal position, has not divided yet, or the two lateral centrioles, having come together at the base of the nucleus, have fused, or one of the two basal centrioles has already migrated to the lower extremity of the spermatid tail to form the distal centriole (fig. 23).

In the early spermatid, while the chromatin is diffusing and found in a fragmentary condition, the X-chromosome retains for a time its long spindle shape and is often found drawn out against the nuclear membrane (fig. 24). After a time, however, it loses its spindle shape and becomes rounded off, so that when the centriole occupies its typical basal position between the nucleus and the nebenkern, the X-chromosome is a very prominent round body, usually towards the centre of the nucleus (fig. 23). It retains this shape for a considerable time. Meanwhile the diffusion of the other chromosomes has proceeded much further, until they are just visible as a few indistinct granulations (figs. 21, 23). Figs. 20, 21, 22, etc., represent male-producing spermatids without the X-chromosome.

Soon after the centriole has reached its basal position a split appears in the nebenkern. This split is always perpendicular to the nuclear membrane, and evidently never develops until after the centriole has migrated to its proper position. The latter body, which, prior to the time of the division of the nebenkern has always retained its minute size, now enlarges very much and forms quite a prominent structure (fig. 27). This enlargement has probably taken place just a short time prior to the nebenkern division. The axial filament, in distinct preparations, is seen to pass along the split, or rather, the hemispheral nebenkern halves lie round the axial filament (fig. 27).

After division the nebenkern halves initiate a process of elongation down the tail region (figs. 27, 29, 30). During this process of elongation the X-chromosome gradually becomes fainter and fainter, whilst the acrosome is seen as a distinct structure in the form of a round body, considerably smaller than the centriole, applied against the nuclear membrane (fig. 30). At first it occupies a basal position, not far from the centriole, but it gradually migrates along the nuclear membrane, where it can be seen in various positions along the side (figs. 28, 29, 30), until afterwards it occupies the position at the anterior tip of the nucleus, still attached to the nuclear membrane (fig. 31). Each of the nebenkern halves appears to be attached to the centriole by a thin thread (fig. 30).

After the elongation of the nebenkern sheaths has proceeded to a certain

stage, the X-chromosome is no longer visible (figs. 33, 34), and has completely dissolved. The latter part of the process of elongation cannot be followed up satisfactorily, as the sheaths lose their staining affinity to a great extent and can no longer be clearly seen (figs. 32, 33); but it may be assumed that they eventually form mere strips ensheathing the axial filament. The centriole remains large and conspicuous throughout the whole process.

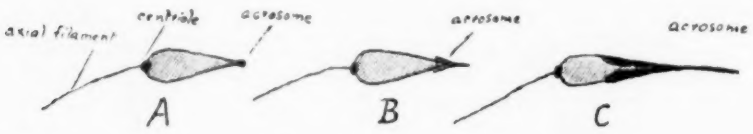
During the period when the nebenkern halves are all comparatively short and well stained, no tendency of a spiral twisting of these halves round each other is noticeable. Such a spiral tendency has been described in other forms, but failure to observe it in this case may be due to the fact that the practically unstained and hence obscure nature of the longer nebenkern sheaths makes an observation like this impossible. In spermatids with a considerably long tail a double series of vesicles is often found down the tail region (figs. 32, 33), there being a string of such vesicles on either side of the axial filament. This phenomenon was first described by Bowen for the Hemiptera. He interprets it as swellings which arise in the nebenkern sheaths and which disappear later again. It must be remembered that at much earlier stages, even as far back as the undivided spherical nebenkern, the latter body already appears vesicular (figs. 21, 24), and the vesicles found in the tails of comparatively old spermatids may have been derived directly from these vesicular mitochondrial structures.

For a considerable time after the nebenkern halves have become obscure the spermatid nucleus retains its round shape. This is a very typical stage (fig. 34). It is about this time that the remaining granulations of chromatin become finally dissolved and the acrosome is typically found at its permanent anterior position. In fig. 37 some cross-sections through the tails of sperms at this stage are shown. A process of elongation in the head region is now initiated (figs. 35, 36).

It is rather a difficult matter to follow up the later part of spermiogenesis. Apparently, during the early stages of the elongation of the head, the acrosome remains a small structure at its anterior tip, but after the head has elongated to a certain degree the acrosome undergoes profound modification in shape and size, eventually becoming a long, spear-like structure (figs. 38, 39). A groove or rather unstained streak is seen running along the middle of the acrosome. It is peculiar that no trace of the acrosome can be found in sperms at the stage represented in fig. 36. If one compares the lengths of the head regions seen in figs. 36 and 38, it is seen that the head is much shorter in the latter. This, however, is most probably due, not to an actual shortage in the latter case, but to the fact that the acrosome has grown posteriorly as well as anteriorly and so envelops and obscures a large portion of the anterior head region. One is inclined to offer the following tentative explanation of what probably occurs (*cf.* text-

figs. A, B, C). Assuming that the head has reached a stage during elongation such as that represented in fig. A, one further assumes that the acrosome now starts growing both anteriorly and posteriorly along two sides of the nucleus (fig. B). These two posterior wings of the acrosome then probably approximate to each other until a mere strip is found separating them (fig. C). This will explain the derivation of fig. 38. Of course it may also be that the acrosome is in the form of a hollow cone fitting over the anterior portion of the head, and fig. 38 may thus be explained as a longitudinal section through the sperm and cone.

Very little is known about the nature and origin of the axial filament. Its constant association with the centriole undoubtedly suggests some sort of relation between the two structures. Thus we find some authors contending that the axial filament grows out of the substance of the basal



centriole. This may very likely be the case, and, as far as is known, no serious objection can be offered against such a view, except that it is rather remarkable that at a time when the filament grows down the tail the centriole itself becomes enlarged, instead of decreasing in size, as would be expected if the filament actually grows out of its substance. This in itself, however, is not sufficient evidence for regarding the above explanation as impossible. There is another interpretation of the origin of the filament, namely, that it is the connection remaining between the basal and distal centrioles when these two bodies separate from each other. This view, however, does not hold in cases where there is no distal centriole, as in the Hemiptera (Bowen), and must consequently be discarded in favour of the above assumption. In any case, it is practically certain that the filament is of centriolar derivation.

During the last stages in spermiogenesis a number of round darkly stained bodies are to be made out in the regions occupied by the sperm tails (fig. 38). These represent part of the debris of spermiogenesis, and very probably are composed of Golgi remnants together with other cast-off material. According to Bowen and Gatenby, they are eventually completely sloughed off from the tail and form no part of the mature sperm. As a matter of fact, Bowen describes the Golgi remnant, and spermatid remnant together with other substances, which collectively form the debris of spermiogenesis, as travelling down the tail and eventually collecting into a

common round mass which is then sloughed off. This mass, he alleges, is taken up by the epithelial cells of the cyst wall. Meves describes a similar phenomenon taking place in the mouse. Such sloughed-off masses are frequently seen in Locust preparations (fig. 40), but we have been unable to find evidence of their being ingested by the epithelial cells.

In the mature sperm the various parts all stain so uniformly dark that their exact relation to each other cannot be made out. However, it is certain that the following structures are present: head (*i.e.* nucleus), acrosome, centriole, and probably mitochondria.

In the above account of the spermiogenesis of the Locust certain phases are very prominent, and may be called typical phases, whilst others, linking up these typical stages, are often very confusing and difficult to interpret. The latter may be called intermediate phases. A true solution of many vexed problems in spermiogenesis simply depends upon a correct interpretation of the intermediate phases. Whether such a differentiation between alternately typical and intermediate phases reveals the true nature of events operating in the living insect is very questionable. One is more apt to think of the various stages as following each other at a perfectly uniform rate, without a pause taking place at certain intervals. Nevertheless, one so often meets a certain stage figuring very prominently in various cysts of the same section or different sections, that, even if it is merely for the sake of convenience, one is justified in making this differentiation. The sequence of the typical phases in the spermiogenesis of the Locust may be summarised as follows:—

1. The young spermatid after the second maturation division with a round nucleus showing the chromosomes as irregular bodies in various stages of dissolution—the oval nebenkern very prominent.

2. The first clear indication of the minute spermatid centriole, often double, situated between the nucleus and the nebenkern.

3. The centriole enlarged and, as such, always single and with a well-developed axial filament proceeding from it.

4. The division of the nebenkern and various stages in the elongation of the nebenkern halves, during which the acrosome gradually migrates anteriorly.

5. The partial loss of staining capacity by the nebenkern halves.

6. The total disappearance of the chromatic fragments in the nucleus and the anterior permanent position of the acrosome.

7. The elongation of the sperm nucleus and the beginning of the migration of various waste substances down the tail.

8. The modification of the acrosome into the perforatorium.

Discussion.

During the whole process of spermatogenesis certain phenomena occur, and in this account certain statements are made which require further discussion and elucidation. This can best be done under the following headings :—

(*a*) *The Centrioles.*—The behaviour of the centriole during spermiogenesis is very puzzling. Various authors give different accounts of the rôle it plays during the development of the sperm. Before general conclusions can be drawn as to its fate in all animals more investigation on this subject is necessary. In order to get an idea of the various views held by some cytologists with regard to this matter, the following accounts may briefly be considered :

1. Buchner, in his Praktikum der Zellenlehre, states that the basal centriole between the nucleus and nebenkern divides, one of the division products going to form the acrosome, whilst the remaining half divides again to give rise to a distal centriole which passes down the tail region.

2. Gatenby gives no concise account of the history of the centriole. He merely mentions the fact of a distal centriole besides the ordinary basal one from which the axial filament proceeds.

3. Bowen treats this matter rather fully, and shows that in some Hemiptera the division of the centriole takes place before it attains the basal position. Hence he also speaks of the double basal centriole, which often appears single owing to the close proximity of the two halves. The axial filament proceeds from one of them only. He states that these halves remain together throughout the whole process, and makes no mention of a distal centriole.

4. Doncaster, in his account of the spermatogenesis of the louse, describes the basal centriole as double, with an axial filament proceeding from each half down the tail. At the distal extremity of each axial filament he finds a swelling which he interprets as the distal centriole, but gives no explanation of its origin.

5. Agar also explains the spermatid centriole as a double structure, the one half of which becomes applied to the nuclear membrane giving insertion to the axial filament, while the other half moves along the filament down the tail.

It will be noticed that there is a certain amount of uniformity in these accounts. Thus most of them speak of a double centriole, a distal centriole, an axial filament, etc. Yet much remains to be explained, as the origin of the various phases and their exact relation to each other are not quite clear.

Our own observations on this matter have to a great extent already been recorded, but further reference may not be out of place here. In the

very young spermatid, soon after the second maturation division, the centriole cannot always be identified. In some Hemiptera it has been found that the centriole becomes closely applied to the nuclear membrane, hence its obscurity. Probably this is also the case in the Locust. Occasionally a granule may be seen in the cytoplasm on the side of the nucleus which may doubtfully be the centriole—doubtfully because it may also be the acrosome. The first time that the centriole is identified with certainty is after its migration to occupy the basal position, between the nucleus and the nebenkern. Here it is a minute granule usually double (fig. 22). An attempt has been made to account for this duality by suggesting that the two centrioles seen at the end of the second maturation division polar spindle (fig. 26) migrate to the basal position in the spermatid, each passing along opposite sides of the nucleus. It appears more likely, however, that the two centrioles migrate to the basal position closely applied to each other and to the nuclear membrane. On reaching that position the halves probably separate again. Thus one of the lateral granules in fig. 25 will be a centriole on its way to its permanent position, and the other the acrosome. One would expect to find certain cells showing three granules along the nuclear membrane, namely, the two basal centrioles and the lateral acrosome. Many hours were spent in futile search for this, but such negative evidence cannot be taken to imply that it is impossible. It must further be added that several cases were found showing a distal centriole in the tail region, so that one of the division products of the basal centriole has very probably migrated downwards to form this distal structure.

The assertion made by Buchner, that the acrosome is derived as a division product of the centriole, is wrong in our opinion. One may indeed very easily be misled to this conclusion by erroneously interpreting the intermediate phases occurring between typical phases ((2) and (3) given above). Thus certain cells show the single minute basal centriole, others show two minute basal granules, which are interpreted as the division products of the single centriole, and others again show a single basal centriole and a lateral granule. This lateral granule is then supposed to be the division product of the basal centriole which is migrating anteriorly to form the acrosome. It may be mentioned here that in the Champy preparations of the Locust the lateral granule shows persistently during stages (4) and (5)—see figs. 28, 29—whereas in the acetic preparations it cannot be detected with certainty at similar stages. This in itself is almost conclusive evidence that the acrosome is not of centriolar origin, as the centriole is never dissolved by acetic fixation.

Another interesting aspect with regard to the centriole is its striking enlargement between phases (2) and (3) (*cf.* figs. 23 and 30). The spermatids in these phases were very carefully examined, with a view to finding out

whether this enlargement is due to the growth of the centriole or to the addition of chromatic material from the nucleus. This latter process has been described by Bowen, who finds a nuclear body in the Pentatomid spermatids which he calls a pseudoblepharoplast. The pseudoblepharoplast is at first seen in various localities in the nucleus, but later comes in close contact with the centriole, so as to practically obscure the latter. He suggests that the pseudoblepharoplast may very likely be the X-chromosome. Now, by referring to fig. 23 it will be seen that a prominent round body and some other chromatic structures are present in the nucleus. This large body in the nucleus is undoubtedly the X-chromosome, and the other structures are some remaining autosomes undergoing diffusion. In fig. 29 all these bodies are still present in the nucleus, but the centriole is much larger. Hence we conclude that the centriole attains its large size by mere growth. Further, the enlarged centriole cannot possibly be a fused product of the X-chromosome plus centriole, as it is found in all the spermatids, whereas the X-chromosome is present in only half, namely, the female-producing germ-cells.

(*b*) *The Mitochondria.*—In the Locust preparations no positive trace of the mitochondria in the spermatogonia and the spermatocytes could be found. These germ-cells in the Molluscs (Gatenby) and in the Lepidoptera (Gatenby and Bowen) contain mitochondria in the form of small round bodies or vesicles with a dark-staining peripheral portion (chromophilic portion) and a central non-staining portion (chromophobic portion). These authors then describe the mitochondrial vesicles as aggregating together and condensing in the spermatid to form the nebenkern or macromitosome. In this form it is met with for the first time in the Locust. It seems that some kind of modification in the technique employed is necessary to reveal the mitochondrial vesicles in the Locust satisfactorily.

(*c*) *The Golgi Apparatus.*—Kopsch discovered that prolonged fixation in 2 per cent. osmic acid reveals the presence of the Golgi bodies in the cytoplasm and stains them black. In the Mollusca, Gatenby finds that these structures are in the form of small rodlets or batonettes arranged in groups in the cytoplasm, the rodlets of each group being applied to the periphery of an archoplasmic zone. Bowen gives a somewhat similar account of these bodies in the Lepidoptera, but asserts that they are found with idiosomic material and not archoplasmic. In the spermatocytes of these forms it has been found that the Golgi rodlets often separate away from the archoplasmic (or idiosomic) zone, each carrying away a portion of that material. Such a small rodlet plus a piece of archoplasm or idiosome forms a Golgi body proper. According to these authors each Golgi body, prior to the division of the cell, undergoes a process of multiple fission (dictyokinesis), giving rise to much smaller structures, called dictyosomes.

Each dictyosome is supposed to be supplied with a minute portion of idiosomic material, although the latter cannot be detected. Bowen describes the dictyosomes in the young Hemipteran spermatid after the second maturation division as aggregating together to reconstitute Golgi bodies, which concentrate chiefly in the region between the nucleus and the nebenkern. Here they fuse usually into a single mass, but sometimes into more, each consisting of Golgi material plus idiosome and called an acroblast. The acrosome is a differentiated product of the acroblast.

In the Lepidoptera there is no great tendency for the Golgi bodies to fuse together into a single acroblast, before the differentiation of the acrosome, but presumably fusion does occur to a certain extent. Here, however, each of the Golgi bodies moves up to the nuclear membrane to deliver its share towards the formation of the acrosome and then moves down the tail of the sperm. The particles moving down the tail are called the Golgi remnants. Bowen strongly contends that the acrosome is not Golgi material only or idiosomic only, but a differentiated product of both these constituents.

The above processes could not be discovered in the Locust. In some osmic preparations minute granulations could be detected in the cytoplasm, which must be taken as Golgi elements. It is remarkable that these granulations were doubtfully present in the spermatogonia, but distinctly in the spermatocytes (fig. 41). The larger number present in the spermatocytes must be due to the multiplication of these bodies during the growing phase. However, during the maturation divisions the Golgi bodies again became obscure, and could only doubtfully be identified. This is probably due to the fact that the dictyosomes, in which form one would expect the Golgi elements to be during division phases, were too minute for identification. In the young spermatid one again meets inclusions, rather indistinct, but which can only be these bodies (figs. 20, 30). In fig. 30 the acrosome is also seen, but the way in which the latter is derived from the Golgi bodies could not be elucidated in these preparations. In the cases where the Golgi granulations were found, no trace of archoplasmic or idiosomic material attached to them could be discerned.

(*d*) *Archoplasm and Idiosome.*—These two terms were used indiscriminately in the above account. But what is exactly understood by these terms, and do they denote the same thing? The real significance of these structures seems very far from clear, despite the fact that one finds frequent allusions to them in cytological works.

Agar defines archoplasm as "the substance composing the system of radiating lines which are seen proceeding from the centriole (centrosome) through the cytoplasm." A somewhat similar definition is given by Gatenby, namely, the dense mass of cytoplasmic material gathered round the centro-

some in the form of a sphere, and he then further asserts that the archoplasm in the germ-cells of some animals often has its periphery studded with Golgi rodlets. In 1896 Meves introduced the term idiozom "für die spezifisch beschaffene Huelle, welche die Centralkoerper in den maennlichen Samenzellen umgiebt." Gatenby contends that Meves' word idiozome is applied to the large zone of archoplasmic material found round the centrosome in spermatids; in other words, he regards the two terms as signifying the same identical substance, the one (archoplasm) probably used more frequently in the case of somatic cells, the other (idiosome) in the case of germ-cells.

On the other hand, Bowen never uses the word archoplasm, but always idiosome, with which substance he also associates the Golgi rodlets. True, he never mentions a case where the centrosome is found in connection with the idiosome, thus apparently violating the definition of this body as originally given by Meves, but he contends that this is not a necessary criterion for its identification, since the body usually known as the idiosome in mammalian germ-cells never contains a centriole. He emphatically declares that the idiosome is not identical with the archoplasm, and that Gatenby's use of the latter term is wrong. He points out that it is generally agreed that the idiosome does not contribute towards the formation of the achromatic division figure (spindle), but that, despite this, many writers still use the terms attraction sphere and archoplasm as synonymous with idiosome. This has led to the term "sphere" being applied as a synonym for idiosome. Bowen advises that the term "sphere" should be dropped on account of its ill-defined meaning, as seen from his classification:

I. Sphere	Attraction sphere	(Van Beneden, '83).
	Archoplasm	(Boveri, '88).
	Archiplasm	(Benda, '91).
	Atrosphere	(Strassburger, '92).
	Centrosphere ?	
II. Sphere	Centrodeutoplasm	(v. Erlanger, '97).
	Idiozom	(Meves, '96).
	(Idiosome).	
	Idiosome	(Regaud, '10).

He contends that the spheres in Group I bear no relation to the spheres in Group II.

The question now arises, which of the two authorities is correct, Gatenby or Bowen? In favour of Gatenby's interpretation is the fact that Bowen does not mention a single instance where both structures are present at the same time in the germ-cell, and yet this is what one would expect, if these

two structures are distinct and separate. But then, if he considers his archoplasm as identical with Meves' idiosome, how is it that one looks in vain in his drawings for the centriole, which Meves defined as being present in the idiosome ? It may of course be that the centriole, soon after division, migrates out of the archoplasmic zone and settles in the cytoplasm or against the nuclear membrane. In favour of Bowen's interpretation may be mentioned the fact that one is inclined to look upon the archoplasm merely as a temporary structure, formed chiefly by the concentration of the spindle fibres at the end of the spindle and hardly as a permanent cell-constituent, which the idiosome presumably should be. If it can be shown that the one is directly derived from the other, then Gatenby's view will probably be correct. On the other hand, if both structures can be shown to be present in the same cell, they must be considered as distinct from each other. It is thus clear that more research is needed before this question can be finally solved.

(*e*) *A Doubtful Light Spherical Body.*—From time to time a light round body was detected in the cytoplasm of the germ-cells. It was found in spermatogonia, growing spermatocytes, and in Metaphases I and II, and showed best in Flemming preparations (figs. 12, 19, 42). Its nature and origin is problematic, but it may very likely be one of the following three substances—archoplasm, idiosome (in Bowen's sense), or mitosome (*i.e.* the spindle remnant). In one case it appeared to have some connection with the spindle, thus suggesting a mitosomal origin, but this could not be ascertained definitely.

(*f*) *Irregularities.*—During these observations cells were found which exhibited remarkable irregularities in their organisation and size, so that one can speak of normal germ-cells and abnormal giant germ-cells. It is very likely that the abnormal cells degenerate after a time and never reach the mature stage, although no definite evidence can be advanced to support this view. This is probably a case of dimegaly, as described by Montgomery in the Hemiptera. Abnormal development of germ-cells has also been described by Gatenby, Federley, Bowen, and others.

Conclusion.

The chromosome numbers in over forty genera of Locusts have by now been worked out, and in practically all cases it has been found that $2n=23$ (male) and 24 (female). The few exceptions which showed smaller chromosome numbers could all be accounted for by secondary linkage of non-homologous chromosomes, and thus in every single instance could the numbers 23 and 24 be adduced. In five genera belonging to the family Tettigidae the chromosome numbers were found to be $2n=13$ (male) and

14 (female). Probably a further study of the chromosomes in this family will bear out its relation, from a chromosome basis, to the Locusts. Although chromosome counts have been made of numerous animals, especially insects, during the last fifteen or twenty years, very little work has been done in the case of certain groups, and when these backward groups have once been investigated, one may probably be able to look forward confidently to some interesting relations between classification in the animal kingdom and chromosome numbers.

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(NOTE.—Part 3. Spermatogenesis of some Pulmonates.
Part 4. Notes on the Dimorphic Spermatozoa of *Paludina*.
Part 5. Gametogenesis and Early Development of *Limnæa stagnalis*, with special reference to the Golgi Apparatus and the Mitochondria.
Part 6. Modern Cytological Technique.)

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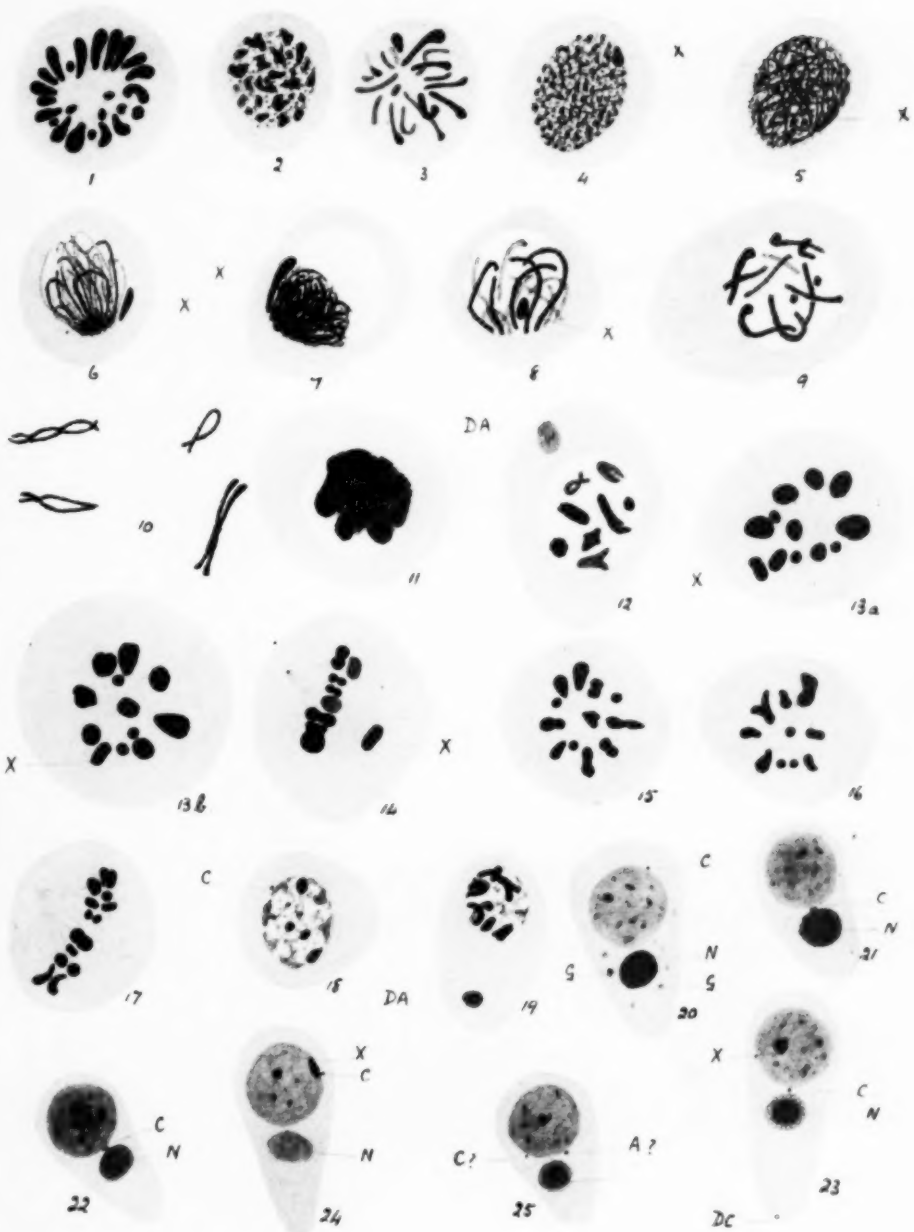
EXPLANATION OF FIGURES.

The drawings were all made by camera lucida. Ocular No. 4 and 1/12 oil immersion (Zeiss) were used.

A. Acrosome.
AF. Axial filament.
C. Centriole.
DA. Doubtful area.
DC. Distal centriole.
G. Golgi body.
GR. Golgi remnant.
H. Head (nucleus).
N. Nebenkern.
NS. Nebenkern sheath.
X. X-chromosome.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NOTE ON THE EXPLICIT (NON-SYMBOLIC) EXPRESSION OF CONCOMITANTS OF BINARY QUANTICS.

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SUMMARY.

1. Definition of $\Delta^s\varphi$ and fundamental equation connecting $\Delta^{s+1}\varphi$, $\Delta^{s-1}\varphi$.
2. Series for transvectant in terms of derivatives so formed.
3. Application to a single binary form. The fundamental concomitants.
4. Series for the Δ-derivatives of transvectants are similar in form to the transvectant series.
5. Examples showing the application of this method to the quantic of infinite order. Some fundamental syzygies.

1. Transvectants can be expressed explicitly by a finite series of terms each consisting of products of a certain derivative form, here defined as follows :—

f, ϕ being binary quantics of orders n, p respectively, the s^{th} polar of ϕ is formed, viz. $\left(\xi\frac{\partial}{\partial x}+\eta\frac{\partial}{\partial y}\right)^s\phi$ and f_y, $-f_x$ substituted for ξ, η respectively.

This defines the form $\Delta^s\phi$ or ϕ_s.

From this definition it will be apparent that the " index " of Δ is neither commutative nor associative; thus $\Delta^p(\Delta^q\phi)$ and $\Delta^q(\Delta^p\phi)$ are not in general equal, and neither is equal to $\Delta^{p+q}\phi$.

We have also $$\phi_s \equiv 0 \text{ when } s>p \quad . \quad . \quad . \quad . \quad (1)$$

and $$f_1=0 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$f_2=\frac{n}{n-1}f\,.\,(f_{xx}f_{yy}-f_{xy}^2) \quad . \quad . \quad . \quad . \quad (3)$$

To prove (3) we put

$$(n-1)f_x=xf_{xx}+yf_{xy}$$
$$(n-1)f_y=xf_{xy}+yf_{yy};$$

then

$$f_2 \equiv f_y^2 f_{xx} - 2f_y f_x f_{xy} + f_x^2 f_{yy}$$
$$= \frac{1}{(n-1)^2}\{f_{xx}f_{yy} - f_{xy}^2\}\{x^2 f_{xx} + 2xy f_{xy} + y^2 f_{yy}\}$$
$$= \frac{nf}{n-1}(f_{xx}f_{yy} - f_{xy}^2).$$

The derivation of ϕ_s in the general cases which follow depends on the following fundamental theorem :

Theorem I.—

$$\phi_{s+1} = \Delta\phi_s + \frac{s(p-s+1)}{n} \cdot \frac{f_2}{f} \cdot \phi_{s-1}.$$

Proof.—

$$\Delta f_x = f_y f_{xx} - f_x f_{xy} = y(f_{xx}f_{yy} - f_{xy}^2)\left(\frac{1}{n-1}\right)$$
$$= y\frac{f_2}{nf} \quad \text{as in (3) above,}$$

$$\text{and } \Delta f_y = -x\frac{f_2}{nf};$$

hence

$$\Delta\phi_s = \Delta\sum_{\lambda}^{s}(-1)^{\lambda} \cdot \frac{s\,!}{\lambda\,!\,s-\lambda\,!} f_y^{s-\lambda} \cdot f_x^{\lambda} \cdot \frac{\partial^s\phi}{\partial y^{\lambda}\partial x^{s-\lambda}}$$
$$= \sum_{\lambda}^{s+1}(-1)^{\lambda} \cdot \frac{s+1\,!}{\lambda\,!\,s-\lambda+1\,!} f_y^{s-\lambda+1} f_x^{\lambda} \frac{\partial^{s+1}\phi}{\partial y^{\lambda}\partial x^{s+1-\lambda}}$$
$$+ \sum_{\lambda}^{s+1}(-1)^{\lambda} \cdot \frac{s\,!}{\lambda\,!\,s-\lambda-1\,!} f_y^{s-\lambda-1} f_x^{\lambda} \cdot \left(\frac{f_2}{nf}\right)\left(-x\frac{\partial^s\phi}{\partial y^{\lambda}\partial x^{s-\lambda}} - y\frac{\partial^s\phi}{\partial y^{\lambda+1}\partial x^{s-\lambda}}\right)$$

and the theorem follows.

2. We define the s^{th} transvectant of two binary quantics ϕ, ψ by a series, thus :

The s^{th} transvectant being denoted by $(\phi\psi)_s$,

$$(\phi\psi)_s \equiv \sum_{\lambda=0}^{\lambda=s}(-1)^{\lambda}\frac{s\,!}{\lambda\,!\,s-\lambda\,!} \frac{\partial^s\phi}{\partial x^{\lambda}\partial y^{s-\lambda}} \quad \frac{\partial^s\psi}{\partial y^{\lambda}\partial x^{s-\lambda}}$$

In the hyperdeterminant notation of Cayley

$$(\phi\psi)_s = \overline{21}^s.$$

In the symbolic notation of Aronhold

$$(\phi\psi)_s=\frac{p\,!}{p-s\,!}\frac{q\,!}{q-s\,!}(\alpha\beta)^s\alpha_x{}^{p-s}\beta_x{}^{q-s},$$

where

$$\alpha_x{}^p\equiv\phi$$
$$\beta_x{}^q\equiv\psi.$$

We proceed to express this transvectant in terms of the ϕ_s, ψ_s. Symbolically,

$$\phi_s=n^s\,.\,\frac{p\,!}{p-s\,!}(b\alpha)(c\alpha)(d\alpha)\ \ldots\ \alpha_x{}^{p-s}b_x{}^{n-1}c_x{}^{n-1}\ \ldots,$$

where

$$\phi\equiv\alpha_x{}^p$$
$$f\equiv b_x{}^n\equiv c_x{}^n\equiv d_x{}^n\ \ldots\ s \text{ letters},$$

and

$$f^s(\phi\psi)_s=\frac{p\,!}{p-s\,!}\frac{q\,!}{q-s\,!}(\alpha\beta)^s\,.\,\alpha_x{}^{p-s}\beta_x{}^{q-s}b_x{}^nc_x{}^nd_x{}^n\ldots$$

hence, using the symbolic identity,

$$(\alpha\beta)k_x=(k\beta)\alpha_x-(k\alpha)\beta_x$$

for each of the s letters b, c, d . . ., multiplying together the respective left-hand and right-hand sides, expanding the latter, and taking account of the substantial identity of the symbols, we get the fundamental theorem:

Theorem II.—

$$n^s\,.\,f^s\,.\,(\phi\psi)_s=\sum_{\lambda=0}^{\lambda=s}(-1)^\lambda\frac{p-\lambda\,!}{p-s\,!}\frac{q-s+\lambda\,!}{q-s\,!}\frac{s\,!}{\lambda\,!\,s-\lambda\,!}\phi_\lambda\psi_{s-\lambda}.$$

Note.—In particular,

$$n^2\,.\,f^2\,.\,(ff)_2=2n(n-1)\,.\,ff_2,$$

which agrees with the result already obtained, since

$$(ff)_2=2(f_{xx}f_{yy}-f_{xy}{}^2).$$

Another important particular case is $(\phi\psi)_1$, the Jacobian of $\phi\psi$:

$$nf(\phi\psi)_1=p\phi\psi_1-q\psi\phi_1\,;$$

an equation which also follows from the identity

$$0\equiv\begin{vmatrix} nf & p\phi & q\psi \\ f_x & \phi_x & \psi_x \\ f_y & \phi_y & \psi_y \end{vmatrix}$$

3. The function ϕ_s is evidently covariant for linear transformation. Therefore $(\phi\psi)_s$ is covariant for linear transformation. For the single binary quantic f we have the n algebraically independent covariants $f, f_2, f_3, \ldots f_n$, in terms of which all concomitants can be expressed.

In particular, we have the $(n-1)$ irreducible and algebraically independent concomitants

$$(ff)_{2s}, \quad s=1, 2 \ldots, \quad (2s \geqslant n)$$

and their Jacobians

$$\Delta(ff)_{2s}.$$

If n is even, there are $(\frac{1}{2}n)$ of the first and $(\frac{1}{2}n)-1$ of the second. If n is odd, $\frac{1}{2}(n-1)$ of the first and $\frac{1}{2}(n-1)$ of the second.

These, with the quantic itself, form an algebraically complete system.

The factor f, but not f^2, occurs in f_2, and therefore in f_3, f_4, etc. The standard form of concomitant will therefore be taken as

$$\sum \mathrm{C} \cdot \frac{f_p^{\alpha} f_q^{\beta} f_r^{\gamma} \ldots}{f^{\alpha+\beta+\gamma} \ldots}$$

where C is numerical, and

$$\mathrm{W} \equiv \alpha p + \beta q + \gamma r + \ldots$$

is the same for each term.

The covariant in this form is integral, of *degree* W in the coefficients and of *order* $\mathrm{W}(n-2)$ in the variables.

The covariant thus expressed may have a factor f^{P} but not $f^{\mathrm{P}+1}$. We propose to call P the *power* of the concomitant and W the *weight*. If the remaining factor be of degree D in the coefficients and order O in the variables,

$$\mathrm{P}+\mathrm{D}=\mathrm{W}$$
$$n\mathrm{P}+\mathrm{O}=(n-2)\mathrm{W};$$

hence

$$(n-2)(\mathrm{P}+\mathrm{D})=n\mathrm{P}+\mathrm{O}.$$

The solutions of this equation point to the possible types of concomitants. They are infinite in number, but "reducible."

If this remaining factor cannot be expressed in terms of concomitants of lower degree, it is said to be "irreducible."

It is desirable to summarise a few fundamental deductions from the general theorem. We observe that, unless there be good reason to the contrary, the most convenient numerical factor of a transvectant is taken, generally such as to make an end-term unity. Further, when the transvectant, or concomitant, is expressed by means of the $f, f_2 \ldots f_n$, the power of f in the denominator is understood, but not expressed save where necessary.

Deductions—

(1) $\Delta f^s(\phi\psi)_s+\frac{\frac{1}{2}(p-q)}{(p-s)(q-s)}f^{s+1}(\phi\psi)_{s+1}$

$$=\tfrac{1}{2}(p+q-2s)\sum_0^{s+1}(-1)^\lambda\phi_\lambda\psi_{s-\lambda+1}(s+1-2\lambda)\frac{p-\lambda\,!}{p-s\,!}\frac{q-s+\lambda-1}{q-s\,!}\frac{s\,!}{\lambda\,!\,s+1-\lambda\,!}.$$

(2) $f^{2s-2}(ff)_{2s}=f_{2s}+\sum_2^{s-1}(-1)^\lambda f_\lambda f_{2s-\lambda}\frac{n-\lambda\,!}{n\,!}\frac{n-2s+\lambda\,!}{n-2s\,!}\frac{2s\,!}{\lambda\,!\,2s-\lambda\,!}$

$$+\tfrac{1}{2}(-1)^s f_2{}^2\frac{n-s\,!}{n\,!}\frac{n-s\,!}{n-2s\,!}\frac{2s\,!}{s\,!\,s\,!}.$$

(3) $\Delta f^{2s-2}(ff)_{2s}=f_{2s+1}$

$$+\sum_2^s(-1)^\lambda\cdot f_\lambda\cdot f_{2s+1-\lambda}(2s+1-2\lambda)\frac{n-\lambda\,!}{n\,!}\frac{n-2s-1+\lambda\,!}{n-2s-1\,!}\frac{2s\,!}{\lambda\,!\,2s+1-\lambda\,!}.$$

(4) $f^{s-1}(f\phi)_s=\phi_s+\sum_{\lambda=2}^{\lambda=s}(-1)^\lambda\cdot\frac{s\,!}{\lambda\,!\,s-\lambda\,!}\frac{n-\lambda\,!}{n\,!}\frac{p-s+\lambda\,!}{p-s\,!}f_\lambda\cdot\phi_{s-\lambda}.$

(5) $f^s\cdot(\phi\phi)_s=\sum_{\lambda=0}^{\lambda=s}(-1)^\lambda\phi_\lambda\phi_{s+1-\lambda}\cdot\frac{s\,!}{\lambda\,!\,s-\lambda\,!}\frac{p-\lambda\,!}{p\,!}\frac{p-s+\lambda\,!}{p-s\,!}.$

This vanishes identically if s is odd. When s is even each term except the middle term occurs twice.

(6) If p, the order of ϕ, is even,

$$f^p\cdot(\phi\phi)_p=\phi\phi_p-\phi_1\phi_{p-1}+\phi_2\phi_{p-2}\ \ldots\ +\tfrac{1}{2}(-1)^{\frac{p}{2}}\phi_{\frac{p}{2}}{}^2,$$

and evidently, by Theorem I, the Jacobian of this vanishes identically as it should do.

Note.—The general Theorem I, viz.

$$\Delta\phi_s=\phi_{s+1}-\frac{s(p-s+1)}{n}\frac{f_2}{f}\phi_{s-1},$$

affords a method for the successive calculation of ϕ_1, ϕ_2, etc., the form of ϕ being given, usually in terms of f, f_2, f_3, etc.

Let us introduce the operator

$$\partial\equiv f_y\frac{\partial}{\partial x}-f_x\frac{\partial}{\partial y},$$

then $(\delta^p)(\delta^q\phi)$ is evidently $\delta^{p+q}\phi$, so that the indices p, q are both commutative and associative. Moreover, the single operator δ is always equivalent to the single operator Δ.

Hence

$$\phi_1=\delta\phi,$$

but

$$\phi_2=\Delta\phi_1+\frac{p}{n}f_2\phi\,;$$

hence

$$\phi_2=\delta^2\phi+\frac{p}{n}f_2\phi$$

$$\phi_3=\Delta\phi_2+\frac{2(p-1)}{n}f_2\phi_1=\delta\phi_2+\frac{2(p-1)}{n}f_2\delta\phi$$

$$=\delta^3\phi+f_2\delta\phi\left(\frac{p}{n}+\frac{2(p-1)}{n}\right)+\frac{p}{n}f_3\phi$$

and so on.

In particular, let us put $H\equiv\frac{f_2}{n}$, $H_1\equiv\delta H$, $H_2\equiv\delta^2 H$, etc. Then

$$nf_2=H$$
$$nf_3=\delta H=H_1$$
$$nf_4=H_2+3(n-2)H^2$$
$$nf_5=H_3+6(n-2)HH_1+4(n-3)HH_1$$
$$=H_3+10n-24HH_1$$
$$nf_6=\delta f_5+5(n-4)Hf_4$$
$$=H_4+15n-44HH_2+10n-24H_1^2+15(n-2)(n-4)H^3,$$

etc.

Hence we have a set of algebraically independent covariants H, H_1 . . . H_{n-1} in terms of which all covariants may be displayed.

This form does not appear to have any particular value; transvectants lose their symmetry when expressed in terms of the H instead of the f.

But for the cubic and quartic the expressions lead at once to the complete sets. Thus—

For the 3-ic

$$f_4\equiv 0\,;$$

hence

$$H_2+3H^2=0.$$

H_1 is an integrating factor, and observing that $\delta f^2=0$, we have

$$\tfrac{1}{2}H_1^2+H^3=f^2\,.\ (40)$$ [It *must* be degree 4 and order 0, since H is (22)]

the fundamental syzygy of the cubic.

For the 4-ic,

$$f_5\equiv 0$$
$$H_3+16HH_1=0.$$

Integrating once,

$$H_2+8H^2=f^2 . (20) \quad [\text{It must be } (20)]$$

multiplying by H_1 and integrating,

$$\tfrac{1}{2}H_1^2+\tfrac{8}{3}H^3=f^2 . H . (20)+f^3 . (30),$$

the fundamental syzygy for the quartic.

But after this the integrating factors are hard to find, except that when n is even the form of the invariant of degree 2 can at once be written down.

The operator δ is, however, useful for finding the second transvectant with respect to f.

We have

$$(f\phi)_2=\phi_2+\frac{p(p-1)}{n(n-1)}f_2\phi$$

$$=\delta^2\phi+\frac{p(p+n-2)}{n(n-1)}f_2\phi,$$

a very useful form.

We remark that, by Theorem I, and suppressing powers of f in the denominators

$$\Delta f_2=f_3$$

$$\Delta f_3=f_4-\frac{3(n-2)}{n}f_2^2$$

$$\Delta f_4=f_5-\frac{4(n-3)}{n}f_2f_3$$

$$\Delta f_5=f_6-\frac{5(n-4)}{n}f_2f_4$$

etc.

In order to express concomitants we form the system $(ff)_{2s}$ of degree 2. The transvectants $(f . (ff)_{2s})_r$ give concomitants of degree 3. Concomitants of degree 4 are formed either as $((ff)_{2p}(ff)_{2q})_r$ or as $\{f(f . (ff)_{2s})_r\}_t$, and so on. Not all of these are irreducible, but apparently very few general propositions as to reducibility can be laid down. The only complete evidence is furnished by the explicit form.

Theoretically we ought to be able to test the reduced degree D (after division by f^D) of a concomitant expressed by the f's by taking account of the fact that $\Delta^{D+1}\equiv 0$ (since f behaves as a constant under the operation of Δ).

This, however, is of little value in practice except when the order is low. It is, for instance, a test of an invariant whose Δ vanishes, of a linear covariant whose Δ^2 vanishes, of a quadratic whose Δ^3 vanishes, and so on.

The following table gives the fundamental concomitants, for the binary quantic of order n, for weights 2 to 12. Those of odd weight (weight =power+degree) are Jacobians. The forms are supposed to be made homogeneous by supplying f or f^2 in the denominator of each term. This table gives, in fact, on substituting for n, all the fundamental concomitants up to and including the duodecimic.

Power.	Degree.	Order.	
0	2	$2n-4$	f_2
0	3	$3n-6$	f_3
2	2	$2n-8$	$f_4 + 3\frac{(n-2)(n-3)}{n(n-1)}f_2^2$
2	3	$3n-10$	$f_5 + 2\frac{(n-3)(n-4)}{n(n-1)}f_2f_3$
4	2	$2n-12$	$f_6 + 15\frac{(n-4)(n-5)}{n(n-1)}f_2f_4 - 10\frac{(n-3)(n-4)(n-5)}{n(n-1)(n-2)}f_3^2$
4	3	$3n-14$	$f_7 + 9\frac{(n-5)(n-6)}{n(n-1)}f_2f_5 - 5\frac{(n-4)(n-5)(n-6)}{n(n-1)(n-2)}f_3f_4$
6	2	$2n-16$	$f_8 + 28\frac{(n-6)(n-7)}{n(n-1)}f_2f_6 - 56\frac{(n-5)(n-6)(n-7)}{n(n-1)(n-2)}f_3f_5 + 35\frac{(n-4)(n-5)(n-6)(n-7)}{n(n-1)(n-2)(n-3)}f_4^2$
6	3	$3n-18$	$f_9 + 20\frac{(n-7)(n-8)}{n(n-1)}f_2f_7 - 28\frac{(n-6)(n-7)(n-8)}{n(n-1)(n-2)}f_3f_6 + 14\frac{(n-5)(n-6)(n-7)(n-8)}{n(n-1)(n-2)(n-3)}f_4f_5$
8	2	$2n-20$	$f_{10} + 45\frac{(n-8)(n-9)}{n(n-1)}f_2f_8 - 120\frac{(n-7)(n-8)(n-9)}{n(n-1)(n-2)}f_3f_7 + 210\frac{(n-6)(n-7)(n-8)(n-9)}{n(n-1)(n-2)(n-3)}f_4f_6 - 126\frac{(n-5)(n-6)(n-7)(n-8)(n-9)}{n(n-1)(n-2)(n-3)(n-4)}f_5^2$
8	3	$3n-22$	$f_{11} + 35\frac{(n-9)(n-10)}{n(n-1)}f_2f_9 - 75\frac{(n-8)(n-9)(n-10)}{n(n-1)(n-2)}f_3f_8 + 90\frac{(n-7)(n-8)(n-9)(n-10)}{n(n-1)(n-2)(n-3)}f_4f_7 - 42\frac{(n-6)(n-7)(n-8)(n-9)(n-10)}{n(n-1)(n-2)(n-3)(n-4)}f_5f_6$
10	2	$2n-24$	$f_{12} + 66\frac{(n-10)(n-11)}{n(n-1)}f_2f_{10} - 220\frac{(n-9)(n-10)(n-11)}{n(n-1)(n-2)}f_3f_9 + 495\frac{(n-8)\ldots(n-11)}{n\ldots(n-3)}f_4f_8 - 792\frac{(n-7)\ldots(n-11)}{n\ldots(n-4)}f_5f_7 + 462\frac{(n-6)\ldots(n-11)}{n\ldots(n-3)}f_6^2$

We remark that 3-partitions, and above, of the weight do not occur; further, that in any form all or none of the terms vanish identically according to the value of n.

Weight of Concomitants.—A concomitant of given weight can be formed—

(*a*) by transvection;

(*b*) by multiplication of concomitants the sum of whose weights is the given weight.

It is therefore necessary to inquire whether linear relations exist among such concomitants, and, if so, what relations.

In the case of the concomitants of a single form we may form the concomitants in terms of the f_2, f_3, etc., and determine, by trial or otherwise, what these relations are. This is, in fact, a very powerful method, and probably the least laborious; but we can also form certain series giving relations between transvectants of different indices.

Such series depend for their establishment on some rather remarkable series for the successive derivatives (Δ, Δ^2, Δ^3, etc.) of transvectants which reveal the fact that these derivatives (which are required for forming transvectants between transvectants) are expressed by series of form precisely similar to those expressing the transvectants; so that a mixed, or complex, transvectant involving a number of forms θ, ϕ, ψ, . . . is expressed as

$$\Sigma\Delta^{\lambda_1}\theta \,.\, \Delta^{\lambda_2}\phi \,.\, \Delta^{\lambda_3}\psi \;\ldots\; C_{\lambda_1\lambda_2\lambda_3} \;\ldots$$

where $\lambda_1+\lambda_2+\lambda_3+\ldots$ is the same for each term, being the weight of the transvectant, and the sum of the indices of the transvectants; *e.g.*

$$((\phi\psi)_r(\theta\chi)_s)_t=\Sigma\phi_\lambda\psi_\mu\theta_\nu\chi_\rho C_{\lambda\mu\nu\rho}$$

where

$$\lambda+\mu+\nu+\rho=r+s+t.$$

4. *The Derivatives of Transvectants.*—We have

$$n^s f^s \,.\, p-s\,!\; q-s\,!\; (\phi\psi)_s=\Sigma(-1)^\lambda\phi_\lambda\psi_{s-\lambda}\frac{s\,!}{\lambda\,!\; s-\lambda\,!}\,p-\lambda\,!\; q-s+\lambda\,!,$$

and, since we may take any convenient numerical multiple to define $(\phi\psi)_s$, we shall assume

$$f^s(\phi\psi)_s=\Sigma(-1)^\lambda\phi_\lambda\psi_{s-\lambda}\,|\,\lambda\,| \qquad . \qquad . \qquad . \qquad \text{I.}$$

where

$$|\,\lambda\,|\equiv\frac{p-\lambda\,!}{\lambda\,!}\,\frac{q-s+\lambda\,!}{s-\lambda\,!}.$$

We proceed to find $\Delta(\phi\psi)_s$, $\Delta^2(\phi\psi)_s$, $\Delta^3(\phi\psi)_s$, etc.

$$\Delta \cdot f^s(\phi\psi)_s = \Sigma(-1)^\lambda \cdot \phi_\lambda \psi_{s+1-\lambda}\{\ |\lambda| - |\lambda-1|\ \}$$

$$-\frac{f_2}{n}\Sigma(-1)^\lambda \phi_\lambda \psi_{s-\lambda-1}\{(s-\lambda)(q-s+\lambda+1)\ |\lambda|\ -(\lambda+1)(p-\lambda)\ |\lambda+1|\}.$$

The coefficient of $\frac{f_2}{n}$ *vanishes identically*; hence

$$\Delta f^s(\phi\psi)_s = \Sigma(-1)^\lambda \phi_\lambda \psi_{s+1-\lambda}\{\ |\lambda| - |\lambda-1|\ \} \quad . \quad . \quad . \quad \text{II.}$$

Proceeding,

$$\Delta^2 f^s \cdot (\phi\psi)_s = \Delta(\Delta f^s(\phi\psi)_s) + \frac{p+q-2s}{n} f_2(\phi\psi)_5,$$

since $p+q-2s$ = order.

Forming the second term, the coefficient of $-\frac{f^2}{n}$ is

$$\Sigma(-1)^\lambda \phi_\lambda \psi_{s-\lambda}\{(s-\lambda+1)(q-s+\lambda)\{\ |\lambda| - |\lambda-1|\ \}$$
$$-(\lambda+1)(p-\lambda)\{\ |\lambda+1| - |\lambda|\ \}.$$

The expression in the bracket is

$$|\lambda|\ \{(s-\lambda+1)(q-s+\lambda)+(\lambda+1)(p-\lambda)\}$$
$$-\{\ |\lambda-1|\ .\ (s-\lambda+1)(q-s+\lambda)+\ |\lambda+1|\ .\ (\lambda+1)(p-\lambda)\},$$

and the second bracket on expanding

$$= |\lambda|\ \{\lambda(p-\lambda+1)+(s-\lambda)(q-s+\lambda+1)\}.$$

Hence the whole expression

$$= |\lambda|\ \{(s-\lambda+1)(q-s+\lambda)+(\lambda+1)(p-\lambda)$$
$$-\lambda(p-\lambda+1)-(s-\lambda)(q-s+\lambda+1)\}$$
$$= |\lambda|\ \{p+q-2s\},$$

so that in $\Delta^2 f^s \cdot (\phi\psi)_s$ *the coefficient of* f_2 *vanishes*, and we get

$$\Delta^2 f^s(\phi\psi)_s = \Sigma(-1)^\lambda \phi_\lambda \psi_{s+2-\lambda}\{\ |\lambda| - 2\,|\lambda-1| + |\lambda-2|\ \} \quad . \quad \text{III.}$$

By making use of the identities which have arisen in the formation of II and III, it appears that

$$\Delta^3 f^s(\phi\psi)_s = \Sigma(-1)^\lambda \phi_\lambda \psi_{s+3-\lambda}\{\ |\lambda| - 3\,|\lambda-1| + 3\,|\lambda-2| - |\lambda-3|\ \},$$

the term in f_2 *vanishing identically.* And generally

$$\Delta^a f^s(\phi\psi)_s = \Sigma(-1)^\lambda \phi_\lambda \psi_{s+a-\lambda}\left\{\sum_0^a (-1)^\mu \frac{a!}{\mu!\,a-\mu!}\ |\lambda-\mu|\ \right\}$$

(the coefficient of f_2 vanishing), which we may write

$$\Delta^a f^s(\phi\psi)_s = \Sigma(-1)^\lambda \phi_\lambda \psi_{s+a-\lambda} \mid \lambda \mid_a,$$

$\mid \lambda \mid_a$ being a series with binomial coefficients.

Complex Transvectants.—Thus we may express $\{(\phi\psi)_s\theta\}_t$, which may be called a complex transvectant, in the form $\Sigma\Sigma\phi_\lambda\psi_\mu\theta_\nu C_{\lambda\mu\nu}$, where $\nu \geqslant t$ and $\lambda+\mu+\nu=s+t$, and generally $((\phi\psi)_{a_1}\theta)_{a_2}$ is expressed in similar form.

If, then, we postulate $a_1+a_2=s+t$, we find that

$$\sum_{s+t=a_1+a_2} C_{a_1a_2}((\phi\psi)_{a_1}\theta)_{a_2} = \sum_{\lambda+\mu+\nu=s+t} \phi_\lambda\psi_\mu\theta_\nu C_{\lambda\mu\nu}$$

and a similar form for $\Sigma(\phi(\psi\theta)a_1)a_2$ with certain restrictions on the values of a_1, a_2. We may therefore expect to find relations between series of complex transvectants of the same weight, of which the series of Gordon and Stroh are examples (see Grace and Young, Algebra of Invariants, ch. iv).

An example of fundamental importance is that "the Jacobian of a Jacobian is reducible."

In fact, $((\phi\psi)_1\theta)_1$ reduces to three terms, $\theta(\phi\psi)_2$, $\phi(\theta\psi)_2$, $\psi(\theta\phi)_2$, affected with numerical coefficients.

Evidently we may extend these series. For example,

$$((\phi\psi)_r(\theta\chi)_s)_t = \Sigma\phi_\lambda\psi_\mu\theta_\nu\chi_\rho \cdot C_{\lambda\mu\nu\rho},$$

where $\lambda+\mu+\nu+\rho=r+s+t$, and so on.

5. *Concomitants of the Quantic of Infinite Order.*—If ϕ and ψ are quantics of orders p, q respectively, then their s^{th} transvectant is of order $p+q-2s$, and is of the form $f^s \cdot (\phi\psi)_s = \Sigma\phi_\lambda\psi_{s-\lambda}C_\lambda$, where C_λ is numerical. The *weight* (sum of suffixes) $=s$, and each term is of *degree* 2 in ϕ and ψ, ignoring the suffixes. Moreover, $\Delta^a f^s(\phi\psi)_s$ is of the same form, namely, of weight $s+a$ and degree 2, terms involving $\dfrac{f_2}{f}$ cancelling, as we have seen.

In forming the concomitants of the binary form f of order n, where n is very large, we put $\phi=\psi=f$, and then Limit $\dfrac{a(p+q-2s-a+1)}{n}$, which appears in the formation of $\Delta^{a+1}f^s \cdot (\phi\psi)_s$, is $2a$.

If $\phi=(ff)_s$, $\psi=f$, then, when expressed in terms of the $f \cdot f_2, f_3$, etc., each term is of degree 3 and, if the transvectant be, for instance, $((ff)_s f)_t$, of weight $s+t$; and so on for all complex transvectants.

In order to illustrate the method a few concomitants will now be derived. We write every concomitant in full save for the numerical factor, which is

adjusted so as to give the end-term coefficient unity. The first few concomitants of degree 2 are ($n = x$)

$$\begin{aligned}
a &\equiv f^2(ff)_2 = ff_2 \\
\beta &= f^4(ff)_4 = ff_4 + 3f_2^2 \\
\gamma &= f^6(ff)_6 = ff_6 + 15f_2f_4 - 10f_3^2 \\
\delta &= f^8(ff)_8 = ff_8 + 28f_2f_6 - 56f_3f_5 + 35f_4^2.
\end{aligned}$$

The corresponding concomitants of degree 3 are $(f\phi)_s$, where

$$\phi = a, \beta, \gamma, \delta \ldots \quad s = 1, 2, 3, 4 \ldots .$$

In order to form these we must first form ϕ_1, ϕ_2, ϕ_3, ϕ_4 . . ., and we will confine ourselves to weight 8.

In forming ϕ_1, ϕ_2 . . . we need not trouble about terms of degree above 2, which automatically vanish, as we know.

$$\begin{aligned}
a &= ff_2 \\
a_1 &= ff_3 \\
a_2 &= ff_4 - f_2^2 \\
a_3 &= ff_5 - 2f_2f_3 \\
a_4 &= ff_6 - f_2f_4 - 2f_3^2 \\
a_5 &= ff_7 + f_2f_5 - 5f_3f_4 \\
a_6 &= ff_8 + 4f_2f_6 - 4f_3f_5 + 5f_4^2.
\end{aligned}$$

$$\begin{aligned}
\beta &= ff_4 + 3f_2^2 \\
\beta_1 &= ff_5 + 2f_2f_3 \\
\beta_2 &= ff_6 - f_2f_4 + 2f_3^2 \\
\beta_3 &= ff_7 - 3f_2f_5 + 3f_3f_4 \\
\beta_4 &= ff_8 - 4f_2f_6 \qquad + 3f_4^2.
\end{aligned}$$

$$\begin{aligned}
\gamma &= ff_6 + 15f_2f_4 - 10f_3^2 \\
\gamma_1 &= ff_7 + 9f_2f_5 - 5f_3f_4 \\
\gamma_2 &= ff_8 + 4f_2f_6 + 4f_3f_5 - 5f_4^2.
\end{aligned}$$

Examples of Concomitants of Degree 3 :—

(1) The Jacobians a_1, β_1, γ_1 are of this type.

(2)
$$\begin{aligned}
f^2(fa)_2 &= fa_2 + 4f_2a \\
&= f^2f_4 + 3ff_2^2,
\end{aligned}$$

hence

$$(f \cdot (ff)_2)_2 = f \cdot (ff)_4.$$

(3)
$$\begin{aligned}
f^2 \cdot (f\beta)_2 &= f\beta_2 + 4f_2\beta \\
&= f^2f_6 + 3ff_2f_4 + 2ff_3^2 + 12f_2^3.
\end{aligned}$$

This may be written

$$f\gamma - 12ff_2f_4 + 12ff_3^2 + 12f_2^3,$$

so that

$$f^3 . (f . (ff)_4)_2 = f^7(ff)_6 - 12(f_2f_4 - f_3^2 - f_2^3).$$

This is the *type* of this concomitant for any value of n. The coefficients will, however, be functions of n. The part $f_2f_4 - f_3^2 - f_2^3$, with proper coefficients, is always irreducible. It is of order $3n-12$ and degree 3.

(4)
$$\begin{aligned} f^3 . (f\beta)_3 &= f\beta_3 + 12f_2\beta_1 - 8f_3\beta \\ &= f^2f_7 - 3ff_2f_5 + 3ff_3f_4 \\ &\quad + 12ff_2f_5 \qquad + 24f_2^2f_3 \\ &\quad - 8ff_3f_4 - 24f_2^2f_3 \\ &= f\gamma_1. \end{aligned}$$

Thus $(f\beta)_3$ is always reducible. For the sextic $\gamma_1 = 0$, and so $(f . (ff)_4)_3 = 0$.

(5)
$$\begin{aligned} f^4(f\beta)_4 &= f\beta_4 + 6 . 4 . f_2\beta_2 - 4 . 8 . f_3\beta_1 + 16f_4\beta \\ &= f^2f_8 - 4ff_2f_6 \qquad + 3ff_4^2 \\ &\quad + 24ff_2f_6 \qquad - 24f_2^2f_4 + 48f_2f_3^2 \\ &\quad - 32ff_3f_5 \qquad - 64f_2f_3^2 \\ &\quad + 16ff_4^2 + 48f_2^2f_4 \\ &= f^2f_8 + 20ff_2f_6 \quad - 32ff_3f_5 + 19ff_4^2 + 24f_2^2f_4 - 16f_2f_3^2. \end{aligned}$$

(6)
$$\begin{aligned} f^2(f\gamma)_2 &= f\gamma_2 + 4f_2\gamma \\ &= f^2f_8 + 4ff_2f_6 + 4ff_3f_5 - 5ff_4^2 \\ &\quad + 4ff_2f_6 \qquad + 60f_2^2f_4 - 40f_2f_3^2 \\ &= f^2f_8 + 8ff_2f_6 + 4ff_3f_5 - 5ff_4^2 + 60f_2^2f_4 - 40f_2^2f_3^2, \end{aligned}$$

hence $5f^4 . (f\beta)_4 - 2f^2(f\gamma)_2$

$$\begin{aligned} &= 3f^2f_8 + 84ff_2f_6 - 168ff_3f_5 + 105ff_4^2 \\ &= 3f\delta\,; \end{aligned}$$

i.e.

$$\begin{aligned} 5f^8 . (f . (ff)_4)_4 - 2f^8 . (f . (ff)_6)_2 &= 3f^9 . (ff)_8 \\ 5 . (f . (ff)_4)_4 - 2(f(ff)_6)_2 &= 3f . (ff)_8. \end{aligned}$$

This shows, for example, that for the sextic $(f . (ff)_4)_4 = 0$.

Concomitants of Degree 4 :—

(1) Let $u \equiv f^2(f\beta)_2 = f^2f_6 + 3ff_2f_4 + 2ff_3^2 + 12f_2^3$ of order *Lt.* $3n$

$$\begin{aligned} u_1 &= f^2f_7 - 3ff_2f_5 + 7ff_3f_4 + 12f_2^2f_3 \\ u_2 &= f^2f_8 - 7ff_2f_6 + 4ff_3f_5 + f_2^2f_4(15 - 21 + 12 + 9) \\ &\quad + 7ff_4^2 + f_2f_3^2(-28 + 24 + 6) \\ &= f^2f_8 - 7ff_2f_6 + 4ff_3f_5 + 15f_2^2f_4 + 2f_2f_3^2 + 7ff_4^2 \end{aligned}$$

$$\begin{aligned} f^2 . (fu)_2 &= fu_2 + 9f_2u \\ &= f^3f_8 + 2f^2f_2f_6 + 4f^2f_3f_5 + 42ff_2^2f_4 + 20ff_2f_3^2 + 108f_2^4 + 7f^2f_4^2 \end{aligned}$$

but

$$f^4(f\beta)_4 = f^2f_8 + 20ff_2f_6 - 32ff_3f_5 + 19ff_4^2 + 24f_2^2f_4 - 16f_2f_3^2.$$

We therefore write

$$f^2 \cdot (fu)_2 - 12\beta^2 = f^3 f_8 + 2f^2 f_2 f_6 + 4f^2 f_3 f_5 + 20 f f_2 f_3^2 - 30 f f_2^2 f_4 - 5 f^2 f_4^2 :$$

hence $5f^5(f\beta)_4 - 2\{f^2(fu)_2 - 12\beta^2\}$

$$= 3f^3 f_8 + 96 f^2 f_2 f_6 - 168 f_2 f_3 f_5 + 105 f^2 f_4^2 + 180 f f_2^2 f_4 - 120 f f_2 f_3^2$$
$$= 3f^2\delta + 12 f f_2 \gamma,$$

hence $5f^9 \cdot (f \cdot (ff)_4)_4 - 2f^8 \cdot (f \cdot (f(ff)_4)_2)_2 + 24 f^8 \{(f \cdot (ff)_4)_2\}^2$

$$= 3f^{10}(ff)_8 + 12 f^8 \cdot (ff)_2 \cdot (ff)_6.$$

A very interesting relation showing that for the sextic and higher orders the second transvectant of the second transvectant of the fourth transvectant, viz. $(((ff)_4 f)_2 f)_2$, is reducible.

N.B.—The result differs from that given in Messrs. Grace and Young's book, ch. iv, p. 68, in that the term $(ff)_2 \times (ff)_6$ also appears.

(2) Consider—

$$f^2(\beta\beta)_2 = \beta\beta_2 - \beta_1^2 \quad \text{on dividing by 2}$$
$$= (ff_4 + 3f_2^2)(ff_6 - f_2 f_4 + 2f_3^2) - (ff_5 + 2f_2 f_3)^2$$
of degree 4 and weight 10
$$= (ff_4 + 3f_2^2)(\gamma - 16 f_2 f_4 + 12 f_3^2) - \beta_1^2$$
$$= \beta\left(\gamma - \frac{16\alpha}{f}\beta + \frac{48 f_2^3}{f} + 12 f_3^2\right) - \beta_1^2 .$$

The form $f_3^2 + \dfrac{4f_2^3}{f}$ occurs implicitly in most forms. Consider, for instance, $f^2 \cdot (f\beta)_2$, which we have found to be

$$f\gamma - 12 f_2 f_4 + 12 f f_3^2 + 12 f_2^3.$$

This may be written

$$f\gamma - \frac{12\alpha}{f}\beta + 12 f\left(\frac{4f_2^3}{f} + f_3^2\right).$$

This form is a reducible concomitant of degree 4 and weight 6. For the cubic alone it is irreducible, being the Hessian of the Hessian, viz. the discriminant.

Observe that

$$\Delta\left(f_3^2 + \frac{4f_2^3}{f}\right) = 2 f_3 f_4 - \frac{6 f_2^2 f_3}{f} + \frac{12 f_2^2 f_3}{f}$$
$$= 2 f_3 f_4 + \frac{6 f_2^2 f_3}{f}$$
$$= \frac{2 f_3}{f}\beta.$$

Note.—In forming the derivatives of a concomitant expressed in terms of f, f_2, f_3, etc., it is to be observed that we must take account of $\frac{f_2}{f}$ in the derivative of a term having f, f^2 . . . as a factor. Otherwise we know that this term must vanish. This knowledge serves as a useful check on the correctness of the arithmetic.

Take, for instance, one of the preceding examples :

$$u \equiv f^6 . (f . (ff)_4)_2$$
$$= f^2 f_6 + 3 f f_2 f_4 + 2 f f_2^3 + 12 f_2^3 ;$$

then Δu in full

$$= f^2 \left(f_7 - \frac{6 f_2}{f} f_5 \right) + 3 f f_3 f_4 + 3 f f_2 \left(f_5 - \frac{4 f_2}{f} f_3 \right) + 4 f f_3 \left(f_4 - \frac{3 f_2}{f} f_2 \right) + 36 f_2^2 f_3$$
$$= f^2 f_7 - 3 f_2 f_5 f + 7 f f_3 f_4 + 12 f_2^2 f_3 ;$$

$\Delta^2 u$ in full

$$= \Delta(\Delta u) + 3 \frac{f_2}{f} u .$$

Now in $\Delta(\Delta u)$ the term $12 f_2^2 f_3$ yields a term

$$12 f_2^2 \left(f_4 - \frac{3 f_2}{f} . f_2 \right),$$

the $\frac{f_2}{f}$ of which cancels with the corresponding term in $\frac{3 f_2}{f} u$, as it should. But the other terms in $\frac{f_2}{f}$ (which are multiplied by f) do not cancel.

Note.—By taking the basic form f, used in defining ϕ_s, of order unity, we have $\phi_{s+1} = \Delta \phi_s$, so that the indices are commutative and associative. If we put $f \equiv \xi y - \eta x$, then transvectants, multiplied by powers of f, are expressed in terms of ordinary *polars*. In extending the method to ternary quantics it is necessary to take account both of ordinary polars and of special polars analogous to those described in the foregoing essay.

If we call ϕ_s a *generalised polar*, section 4 demonstrates that transvectants, and their generalised polars, are expressible, when multiplied by an appropriate power of the basic form, in terms of generalised polars of the forms involved.

GUNDLACHIA AT MALVERN, AND AN EXAMINATION OF THE RADULAE OF OTHER INTERMEDIATE HOSTS OF THE TREMATODE PARASITIC WORMS IN NATAL.

By F. G. Cawston, M.D. Cantab.

(With Plates III and IV.)

Very few examples of the genus *Gundlachia* have been recorded from South Africa, and none of these have yet been examined as possible carriers of trematode worms; although the presence of cercariae in *Burnupia trapezoidea* Boettger from the Free State and in *Burnupia? capensis natalensis* from the Umbilo river at Escombe, Natal, as well as in *Burnupia* sp.? from the Umhlangana at Avoca and in *Ferrissia? burnupi* from Malvern and the Botanic Gardens at Durban, suggested that this subfamily of *Ancylidae* might occasionally prove to be an intermediate host of trematode parasites.

In November 1924 I visited a small pool close to the Government school at Malvern. I had already collected numerous *Ferrissiae* and a freshwater tortoise, *Sternothaerus sinuatus* Smith, infested with *Spirurid* larvae, from this pool.

Attached to the rushes and water-hyacinths were numerous examples of *Gundlachia*, resembling *G. farquhari* Walker, the oval shell varying in length from 2–3 mm. One of the shells measured 2·5 by 1·675 mm., the septum covering about half of the aperture. The smaller portion of the shell, which one is apt to mistake for a smaller one attached to a larger, measured 2·1 by 0·875 mm.; it extended 0·625 mm. beyond the extremity of the shell from which it grew. Microscopic examination under a twelfth magnification revealed a radula composed of a central bicuspid tooth, on each side of which were nine oblique lateral teeth, each with four blunt cusps, and six rows of marginal teeth with five cusps, one of the cusps being longer than the rest. The radula measured 0·75 mm. in length, and consisted of about one hundred and fifty rows of teeth, presenting the appearance of a ribbon. Unlike the teeth of other species I have examined, the overhanging process (" projectile " of some authors) of the marginal and lateral teeth was markedly oblique, the inner extremity lying against the side of the adjacent tooth.

In the liver-substance of this example was a sporocyst containing cercariae with undivided tail and two suckers. No eye-spots were visible. The head measured $\frac{1}{30}$ mm. in length and $\frac{1}{60}$ mm. in breadth; the tail was half the length of the head. It is possible that amongst the numerous *Ferrissiae* obtained from this pool in July, many of which were infested with styletted cercariae, were immature examples of this *Gundlachia*, whose septate process had not been formed at that time of the year.

Examination of the radula of *Planorbis costulatus* from South Coast Junction, in an example whose shell measured 5 mm. in diameter, showed a central bicuspid tooth, several tricuspid lateral teeth, and marginal teeth with cusps divided into five or six smaller cusps; the overhanging process was not so oblique as that seen in the teeth of *Gundlachia*.

An example of *Segmentina planodiscus*, also 5 mm. in diameter, revealed a central bicuspid tooth, tricuspid laterals, and marginals with five cusps. Towards the centre of the radula there were about fifty teeth in each row.

Planorbis pfeifferi, with a shell 7 mm. in diameter, showed a central bicuspid tooth with a well-expanded base, several oblique tricuspid teeth, and marginal teeth possessing cusps divided into eight to ten denticles, presenting the appearance of the outstretched hand. In this species the overhanging process is well developed, looking more like a plate than a ridge or hook. The radula is thus characteristic of that possessed by the commonest intermediate hosts of trematode worms in Natal, namely, *Physopsis africana*, *Limnaea natalensis*, *Isidora tropica*, *Isidora forskali*, *Planorbis pfeifferi*, and *Segmentina planodiscus*. Nevertheless, *Physopsis africana* sometimes, and *Limnaea natalensis* commonly, possesses a unicuspid central tooth, and, even in the lateral teeth in the anterior rows, the overhanging plate may be free from cusps.

An attempt was made to compare examples of the various species at the same age and to compare examples of the same species at various ages, and to determine the constancy in the species as well as slight changes that take place in the development. No certain evidence was forthcoming in support of the tempting view that the marginal teeth developed from the lateral ones, or that there was any increase in the number of lateral teeth as the animal grew; though there was certainly reason to believe that the number of marginal teeth increase with the age of the animal, the older examples showing more marginal teeth than the immature ones. There would also appear to be a definite increase in the number of rows of teeth in the older animals, and this increase would appear to be the result of more rows being formed at the posterior extremity of the radula. Generally speaking, the central tooth of *Limnaea natalensis* is tall and unicuspid. Even in an example whose shell was only 3 mm. in length there were six tricuspid lateral teeth, with heavy cusps usually extending to the basal margin.

The teeth were already 0·3 mm. in height and of almost the same breadth; the marginal teeth were also similar to those of the more mature animal, which possesses from seven to nine lateral and from ten to twenty marginal teeth.

Physopsis africana, with a shell 7 mm. in length, showed a central bicuspid tooth; only occasionally is the central tooth unicuspid. There were nine lateral teeth and twelve marginal ones on either side. This is about the usual number in the adult. The base of the central tooth is expanded, more like that of *Isidora* than of the central tooth of *Limnaea natalensis*, so that the laterals and marginals are more oblique than those of *Limnaea natalensis*. As in *Limnaea natalensis* the mesocone and endocone of the lateral teeth are usually united for part of their length. The marginals are characteristic of the group, the divided cusps extending well below the basal margin. There is usually a well-marked sudden change from the character of the lateral teeth to that of the marginal at the seventh to the ninth tooth, on each side.

The cusps of *Isidora tropica* would appear to be slightly shorter and more distinct; usually the three cusps of the lateral teeth are divided throughout their length. The base of the central tooth is more expanded than that of *Physopsis africana*, and considerably more expanded than the base of the central tooth of *Limnaea natalensis*, thus rendering the lateral and marginal teeth very oblique. As in *Isidora tropica*, *Isidora forskali*, with a shell 7 mm. in length, showed a bicuspid central tooth, several tricuspid lateral teeth, and the marginal teeth showed a gradual increase in the development of the denticles as the outer border of the radula was approached. Whilst the teeth of *Isidora tropica* are 0·3 mm. in height, those of *Isidora forskali* are only 0·2 mm.

Melanoides tuberculata, with a shell 7 mm. in length, possessed a central tooth with six cusps, and one lateral tooth, 0·1 mm. in length, with five cusps. The radula consisted of about seventy rows of three teeth, arranged so as to overlap one another; the radula was over a millimetre in length and 0·175 mm. in breadth. These observations were confirmed by the examination of more mature examples of the various species.

The radula was separated from the rest of the animal and cleaned with ether before being examined and the measurements taken, using a twelfth magnification for the finer details, the scale being inserted into the eye-piece of the microscope.

The cleaned radula was mounted in Canada balsam as a permanent preparation, but the best results were obtained from the freshly prepared radula.

The shells were drawn by holding the example firmly in the hand at a distance of about 12 inches from the paper, on which was printed minute

squares $\frac{1}{8}$ of an inch in breadth. The outline was thus traced on an enlarged scale similarly to the use of a camera lucida.

EXPLANATION OF PLATES.

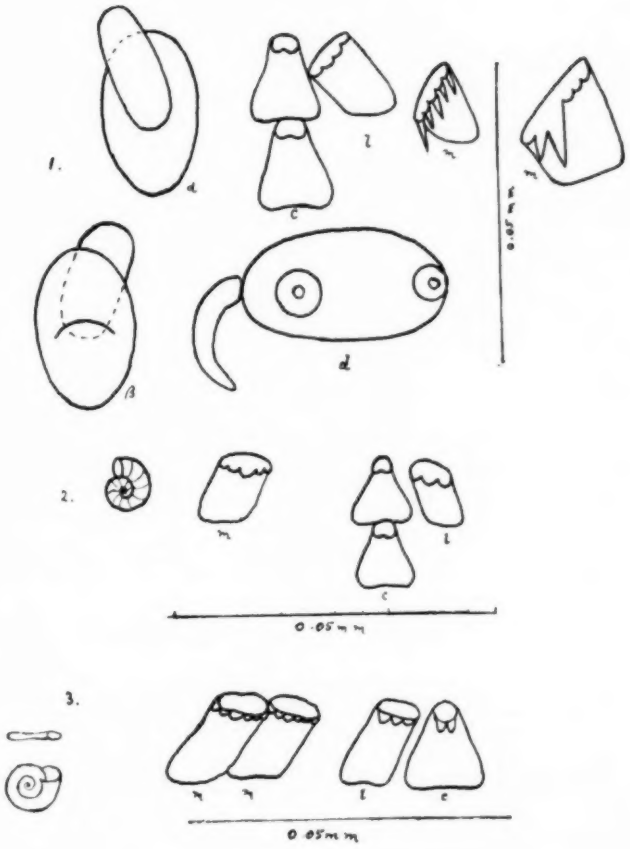
Plate III.

FIG.

1. *Gundlachia* sp. ? ×10. *a*, Surface view ; *β*, ventral view ; *c*, central tooth ; *l*, lateral tooth ; *m*, marginal tooth ; *d*, cercaria.
2. *Segmentina planodiscus* M. & P. ×2.
3. *Planorbis costulatus* Krauss. ×2.

Plate IV.

1. *Melanoides tuberculata* Müll., slightly enlarged. *c*, Central tooth ; *l*, lateral tooth.
2. *Limnaea natalensis* Krs., natural size. *c*, Central tooth ; *l*, lateral tooth ; *m*, marginal tooth.
3. *Physopsis africana* Krs., natural size.
4. *Isidora tropica* (Krs.), natural size.
5. *Isidora forskali* Ehrenb. ×2.
6. *Planorbis pfeifferi* Krs., slightly enlarged.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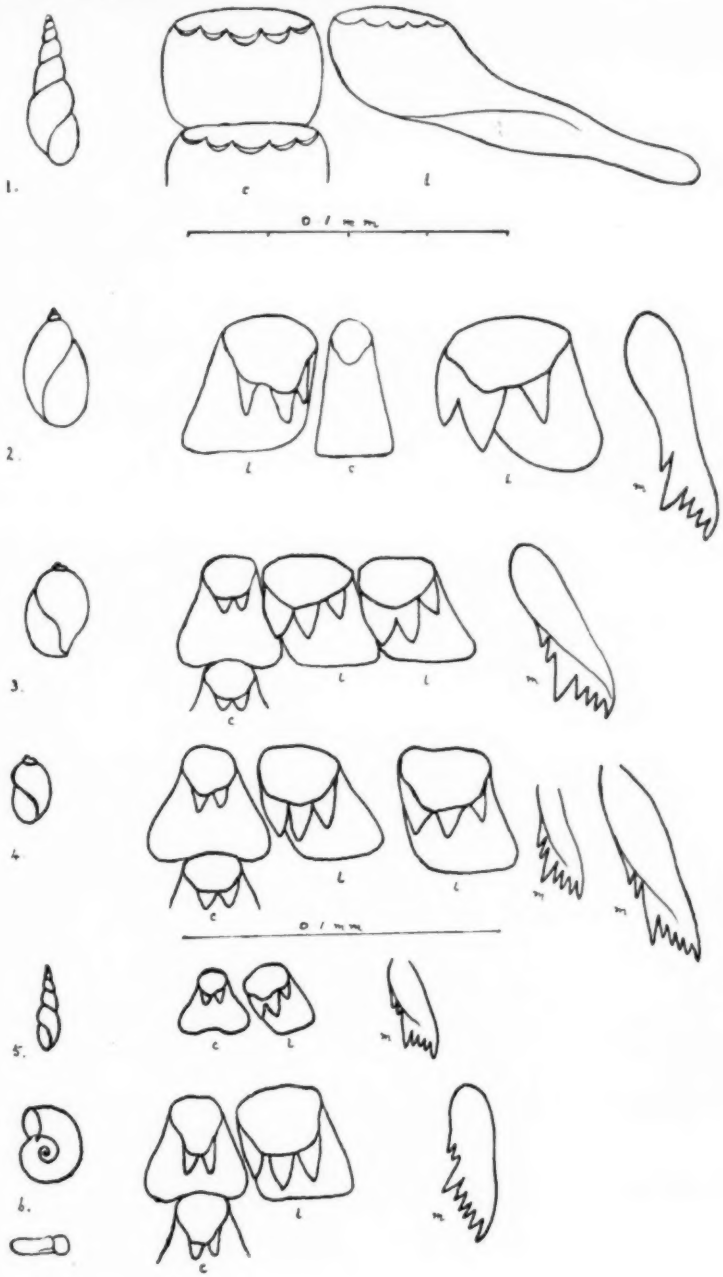
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NOTE ON THE SUM OF THE SIGNED PRIMARY MINORS OF A PERSYMMETRIC CONTINUANT.

By Sir Thomas Muir, F.R.S.

1. In the *Messenger of Mathematics* for 1898 * Scott published the equality

$$\begin{vmatrix} . & 1 & 1 & 1 & 1 & \dots \\ 1 & c & a & . & . & \dots \\ 1 & b & c & a & . & \dots \\ 1 & . & b & c & a & \dots \\ 1 & . & . & b & c & \dots \\ . & . & . & . & . & \dots \end{vmatrix}_{n+1} = \frac{u^{n+1}+v^{n+1}}{(a+b+c)^2} - \frac{(n+1)c(u^{n+1}+v^{n+1})}{(a+b+c)(u-v)^2} + \frac{2ab(n+1)(u^n+v^n)}{(a+b+c)(u-v)^2} - \frac{(-a)^{n+1}+(-b)^{n+1}}{(a+b+c)^2},$$

where u, v are the roots of the equation

$$x^2-cx+ab=0.$$

Apparently it was given merely as an interesting result under the head of bordering, but it is important also to note that the determinant, D_{n+1} say, is an expression for the nègative sum of the signed primary minors of the continuant to which the bordering row and column have been affixed. The method employed for evaluation will be evident from the form of the result: in the same notation the continuant itself, K_n say, had previously been found in like fashion to be equal to $(u^{n+1}-v^{n+1})/(u-v)$.

2. Viewed as a general formula meant to be useful on occasion when the value of the determinant may be wanted for any particular order, the result is conspicuously useless: for example, it is anything but a help towards obtaining the value of

$$\begin{vmatrix} . & 1 & 1 \\ 1 & c & a \\ 1 & b & c \end{vmatrix} \quad i.e.\ a+b-2c$$

to be told that it is

$$\frac{u^3+v^3}{(a+b+c)^2} - \frac{3c(u^3+v^3)}{(a+b+c)(u-v)^2} + \dots,$$

not merely because as a preliminary u^3+v^3, u^2+v^2 have to be found, but because of the tiresome divisions that have to be performed afterwards.

* viii, pp. 131–138.

The formula does not even bear evidence that the said divisions must necessarily be taken in a particular order—that, in fact, it ought to be written in the form

$$\left[\frac{u^{n+1}+v^{n+1}-(-a)^{n+1}-(-b)^{n+1}}{a+b+c}+(n+1)\frac{2ab(u^n+v^n)-c(u^{n+1}+v^{n+1})}{(u-v)^2}\right]/(a+b+c),$$

because here the divisions indicated can be performed in each case without remainder. Some little insight into this is got by examining more closely the two fractions involved. The numerator of the first

$$=-(-b)^{n+1}\left\{-\left(-\frac{u}{b}\right)^{n+1}-\left(-\frac{v}{b}\right)^{n+1}+\left(\frac{a}{b}\right)^{n+1}+1\right\}$$

$$=-(-b)^{n+1}\left\{\left(-\frac{u}{b}\right)^{n+1}-1\right\}\cdot\left\{\left(-\frac{v}{b}\right)^{n+1}-1\right\}$$

$$=-\left\{u^{n+1}-(-b)^{n+1}\right\}\cdot\left\{v^{n+1}-(-b)^{n+1}\right\}\cdot\frac{1}{(-b)^{n+1}}$$

and the denominator being

$$=(u+b)(v+b)\cdot\frac{1}{b},$$

we have for the first fraction

$$\frac{u^{n+1}-(-b)^{n+1}}{u+b}\cdot\frac{v^{n+1}-(-b)^{n+1}}{v+b}\cdot\frac{1}{(-b)^n},$$

where the divisions are easily dealt with.

Similarly, the numerator of the second fraction

$$\begin{aligned}&=2ab(u^n+v^n)-(u+v)(u^{n+1}+v^{n+1})\\&=2uv(u^n+v^n)-(u^{n+2}+v^{n+2})-uv(u^n+v^n)\\&=uv(u^n+v^n)-(u^{n+2}+v^{n+2})\\&=-(u^{n+1}-v^{n+1})(u-v)\,;\end{aligned}$$

and the denominator being $(u-v)^2$ the fraction itself is

$$-\frac{u^{n+1}-v^{n+1}}{u-v},$$

or, curiously enough, $-K_n$, where the division again is of the simplest. The expression for D_{n+1} thus becomes

$$\left\{\frac{u^{n+1}-(-b)^{n+1}}{u+b}\cdot\frac{v^{n+1}-(-b)^{n+1}}{v+b}\cdot\frac{1}{(-b)^n}-(n+1)\frac{u^{n+1}-v^{n+1}}{u-v}\right\}/(a+b+c)\ldots\text{(I)}$$

3. But, further, since

$$\frac{u^{n+1}-(-b)^{n+1}}{u-(-b)}=u^n-u^{n-1}b+u^{n-2}b^2-\ \ldots\ +u(-b)^{n-1}+(-b)^n,$$

and

$$\frac{v^{n+1}-(-b)^{n+1}}{v-(-b)}=v^n-v^{n-1}b+v^{n-2}b^2-\ \ldots\ +v(-b)^{n-1}+(-b)^n,$$

their product

$$\begin{aligned}
&=u^nv^n-u^{n-1}v^{n-1}(u+b)b+u^{n-2}v^{n-2}(u^2+uv+v^2)b^2-\ \ldots\\
&\qquad\ldots+(u^2+uv+v^2)b^{2n-2}-(u+v)b^{2n-1}+b^{2n}\\
&=a^nb^n-a^{n-1}b^n(u+v)+a^{n-2}b^n(u^2+uv+v^2)-\ \ldots\\
&\qquad+b^{2n}-b^{2n-1}(u+v)+b^{2n-2}(u^2+uv+v^2)-\\
&=b^n\left\{(a^n+b^n)-(a^{n-1}+b^{n-1})(u+v)+(a^{n-2}+b^{n-2})(u^2+uv+v^2)-\ \ldots\right\},
\end{aligned}$$

and consequently the first fraction of the result in the preceding paragraph is

$$(-1)^n\left\{(a^n+b^n)-(a^{n-1}+b^{n-1})\mathrm{K}_1+(a^{n-2}+b^{n-2})\mathrm{K}_2-\ \ldots\ +(-1)^n\mathrm{K}_n\right\}.$$

Adding to this the second fraction $-(n+1)\mathrm{K}_n$, we obtain

$$\mathrm{D}_{n+1}=\left\{-n\mathrm{K}_n-(a+b)\mathrm{K}_{n-1}+(a^2+b^2)\mathrm{K}_{n-2}-\ \ldots\ +(-1)^n(a^n+b^n)\right\}/(a+b+c)\ \ldots\ (\mathrm{II})$$

a more interesting and less troublesome form of the result than either of the two preceding, but retaining still the blot of division by $a+b+c$.

4. Failing any further improvement in this direction, let us turn to an examination of the recurrence-formula. The last column of the determinant being

$$1\quad 0\quad 0\quad \ldots\quad 0\quad a\quad c$$

and the last row

$$1\quad 0\quad 0\quad \ldots\quad 0\quad b\quad c,$$

if we expand according to products of elements of these two lines we obtain five terms, the first factors of which are

$$c,\quad a\,.\,b,\quad a\,.\,1,\quad b\,.\,1,\quad 1\,.\,1,$$

and the first, second, and fifth cofactors

$$\mathrm{D}_n,\quad -\mathrm{D}_{n-1},\quad -\mathrm{K}_{n-1}.$$

The remaining two terms are, in the case where n is 6,

$$a\begin{vmatrix} 1 & 1 & 1 & 1 & 1\\ c & a & . & . & .\\ b & c & a & . & .\\ . & b & c & a & .\\ . & . & b & c & a \end{vmatrix},\quad b\begin{vmatrix} 1 & c & a & . & .\\ 1 & b & c & a & .\\ 1 & . & b & c & a\\ 1 & . & . & b & c\\ 1 & . & . & . & b \end{vmatrix};$$

and, if we note that either is got from the other by the interchange of a and b, and that the first is equal to

$$aK_4+a^2\begin{vmatrix}1&1&1&1\\c&a&.&.\\b&c&a&.\\.&b&c&a\end{vmatrix}=aK_4-a^2K_3+a^3\begin{vmatrix}1&1&1\\c&a&.\\b&c&a\end{vmatrix}$$
$$=aK_4-a^2K_3+a^3K_2+a^4K+a^5,$$

we see that the sum of the two must be equal to

$$(a+b)K_4-(a^2+b^2)K_3+(a^3+b^3)K_2-(a^4+b^4)K_1+(a^5+b^5).$$

The recurrence-formula which we have thus reached is

$$D_{n+1}=cD_n-abD_{n-1}-X_{n-1},$$

where

$$X_{n-1}=K_{n-1}-(a+b)K_{n-2}+\ldots \quad . \quad . \qquad \text{(III)}$$

5. X_{n-1}, however, we have seen before, for the result of § 3 may be written

$$(a+b+c)D_n=-nK_{n-1}+K_{n-1}-(a+b)K_{n-2}+\ldots$$
$$=-nK_{n-1}+X_{n-1}.$$

Consequently, by substitution from this we have

$$D_{n+1}=cD_n-abD_{n-1}-\{(a+b+c)D_n+nK_{n-1}\}$$

and therefore

$$D_{n+1}+(a+b)D_n+abD_{n-1}=-nK_{n-1} \quad . \quad . \qquad \text{(IV)}$$

an unexpected result which ought to be directly derivable from a consideration of the determinant itself.

6. The chief usefulness of it, of course, is that we can at once find from it the corresponding recurrent—that is to say, a determinant expression for D_{n+1} free of other D's. This is

$$D_{n+1}=(-1)^n\begin{vmatrix}-2K_1&1&.&,&\ldots\\-3K_2&a+b&1&.&\ldots\\-4K_3&ab&a+b&1&\ldots\\-5K_4&.&ab&a+b&\ldots\\.&.&.&.&\ldots\end{vmatrix}_{n-1}+(-1)^n\begin{vmatrix}a+b&1&.&.&\ldots\\ab&a+b&1&.&\ldots\\.&ab&a+b&1&\ldots\\.&.&ab&a+b&\ldots\\.&.&.&.&\ldots\end{vmatrix}_{n-1} \qquad \text{(V)}$$

the non-determinant form of which is still simpler. For the second determinant $=(a^n-b^n)/(a-b)$, and the cofactors of $-2K_1$, $-3K_2$ . . . in the first determinant are of the same form as the second determinant, consequently we have

$$D_{n+1}=-nK_{n-1}+(n-1)(a+b)K_{n-2}-(n-2)(a^2+ab+b^2)K_{n-3}+\ldots$$
$$+(-1)^n(a^{n-1}+a^{n-2}b+\ldots+b^{n-1}) \qquad \text{(VI)}$$

As the sequence of terms on the right is readily followed, and the K's are easily got from knowing that

$$K_1=c,\ K_2=c^2-ab,\ \text{and}\ K_n=cK_{n-1}-abK_{n-2},$$

this last form for D_{n+1} is of some real importance.

7. With the help of it we could find the expansion of D_{n+1} according to descending powers of c. We should then no longer have the K's in the expansion, but only that part of them, Z say, which is independent of c. In this way the use of a recurrence-formula would not be entailed, for the law of formation of the Z's is quite simple:

$$Z_1=a+b,\quad -Z_2=a^2-2ab+b^2,\quad Z_3=a^3-2a^2b-2ab^2+b^3,$$
$$-Z_4=a^4-2a^3b+3a^2b^2-2ab^3+b^4,\quad Z_5=a^5-2a^4b^2+3a^3b^2+3a^2b^3-2ab^4+b^5\ \ldots,$$

where, it is interesting to note in passing, because of the symmetry with respect to a and b, the odd-numbered Z's are divisible by $a+b$. On the other hand, the law of the sequence of the terms of the new expansion is not so simple, one curious part of it being that $a+b$ is a factor of every even-numbered term, and that it has along with it as a cofactor the corresponding part of the preceding term. For example,

$$D_6=-5c^4+4c^3(a+b)-3c^2(Z_2-2ab)+2c(a+b)(Z_2-2ab)-Z_4.$$

RONDEBOSCH, S.A.,
3rd December 1924.

CONTRIBUTIONS TO OUR KNOWLEDGE OF THE FRESHWATER ALGAE OF AFRICA.

6. *Some Freshwater Algae from Stellenbosch, Cape of Good Hope.*

By W. J. Hodgetts, D.Sc.

(Communicated by Miss E. L. Stephens.)

(With 16 figures in the Text.)

The series of freshwater algae from Stellenbosch dealt with in this paper was very kindly supplied to me by Miss E. L. Stephens, of the Botanical Department, University of Cape Town, to whom I am also indebted for various points of information regarding the collection. There are forty-five samples in all, and they were collected at various times by Miss A. V. Duthie, of the University of Stellenbosch.

The present paper is an addition to the series of "Contributions to our Knowledge of the Freshwater Algae of Africa," by Professor F. E. Fritsch and his co-workers. Five of these "Contributions" have already appeared, those which are of more particular interest in comparison with the present collection being No. 2,* which deals with the freshwater algae in the herbarium of the South African Museum; No. 3,† an account of algae from the Transkei Territories, Cape Colony; and No. 4,‡ a report on freshwater and terrestrial algae from Natal. Many of the species recorded from Stellenbosch in the present paper have also been observed by Professor Fritsch from other parts of South Africa, as of course might be expected.

The district of Stellenbosch § lies some twenty-five miles due east of Cape Town. The rainfall averages about thirty inches per annum, the greater part of which occurs during the winter months. With few exceptions, the samples of algae dealt with in this paper were collected on the Stellenbosch Flats, upon which the town itself is situated. During the long dry summer the depressions and ditches on these flats are waterless, but they rapidly fill with water during the rainy season.

* Ann. S.A. Mus., ix, 483–611, 1918.

† Trans. Roy. Soc. S. Africa, ix, 1–72, 1921.

‡ *Ibid.*, xi, 297–398, 1924.

§ Latitude 34 and longitude 19 cross in Stellenbosch.

The total number of species here recorded is 185, of which 53 are Desmids and 67 Diatoms; while 9 species, 8 varieties, and several forms have been described as new. Perhaps the most noteworthy feature about the collection is the relatively rather large number of species of *Cosmarium* and *Closterium*, other genera of Desmids, however, being generally scarce or absent. The species of *Cosmarium* recorded number 22, of which 2 were in conjugation, while 10 species of *Closterium* were present, 3 in conjugation. The relative scarcity of *Staurastrum* and absence of *Euastrum* are at once noticed; and it may be mentioned that these two genera were generally scarce in the previous collections from South Africa worked out by Professor Fritsch; while *Staurastrum* was scarce and *Euastrum* absent in the series of freshwater algae from South-West Africa which was the subject of a paper by the late Professor G. S. West (Ann. S.A. Mus., ix, 61–90, 1912). Fritsch and Stephens, however, remark (Trans. Roy. Soc. S. Afr., ix, p. 2, 1921) that the scarcity of *Staurastrum* and *Euastrum* does not apply to South Africa generally.

The presence of a new species of *Microchaete* and a new variety of *Microchaete diplosiphon* is interesting, as this genus does not appear to have been previously recorded from South Africa.

Diatoms were generally scarce in the present collection, and the number of species recorded is comparatively small and not very noteworthy.

I should like here to express my very best thanks to Professor F. E. Fritsch for very kindly giving me valuable advice upon the doubtful forms and the new species recorded below; and also to Professor R. H. Yapp of the University of Birmingham for kindly allowing me to consult various books and papers in the collection which previously formed part of the library of the late Professor G. S. West. I am also greatly indebted to Miss Stephens for very kindly sending me this series of algae, and for information regarding the localities.

In the following enumeration of the samples the number of each is that given by Miss Stephens, and corresponds to the number in her larger collection, while the date is that on which the specimen was collected (by Miss A. V. Duthie). Only the chief species present in each tube are mentioned.

347. April 24, 1915. In old water-culture, Botanical Laboratory, Stellenbosch. (*Chlorococcum olivaceum*.)

348. April 24, 1915. Forming dark green scum on sides of glass jar and on surface of water, Botanical Laboratory, Stellenbosch. (*Microthamnion Kützingianum*, few Diatoms.)

349. April 24, 1915. In glass water-tank; floating in water, and dark green in colour, Botanical Laboratory, Stellenbosch. (*Chaetomorpha herbipolensis*.)

350. April 27, 1915. Sides of pool near Stellenbosch railway station. (*Phormidium retzii*, *Ph. tenue*, *Hormidium flaccidum*.)

351. April 27, 1915. Sides of pool, Stellenbosch. (*Phormidium autumnale*, *Ph. corium*, few Diatoms.)

352. April 27, 1915. Sides of zinc water-tank in greenhouse, Stellenbosch. (*Aphanothece conferta*, *Phormidium tenue*, *Protococcus antarcticus*, *Hormidium flaccidum*, few Diatoms.)

353. April 27, 1915. Sides of zinc water-tank in greenhouse, Stellenbosch. (*Chroococcus minor*, *Protococcus antarcticus*.)

354. April 27, 1915. From furrow at side of street, Stellenbosch. (*Oscillatoria amphibia*, *O. tenuis*.)

355. April 27, 1915. Sides of brick water-furrow, forming a dark green leathery layer, Stellenbosch. (*Phormidium corium*, *P. autumnale*, *P. tenue*.)

356. April 27, 1915. Between exposed roots of oak tree, over which water was dripping, in ditch on flats near Stellenbosch. (*Ulothrix variabilis*, *Phormidium corium*.)

357. May 11, 1915. Pool on flats, near Stellenbosch. (*Zygnema* sp., *Closterium spinosporum* sp. n., *Staurastrum orbiculare* var. *depressum*, *Cosmarium Boeckii*, *Scenedesmus* spp., etc.)

358. May 11, 1915. Pool on flats near Stellenbosch. (*Zygnema stellinum*, *Closterium spinosporum*, *Scenedesmus* spp., etc.)

359. May 11, 1915. On outside of water-cask over which water was dripping, Stellenbosch Flats. (*Ulothrix variabilis*, *Synedra Vaucheriae*, *Gomphonema* spp.)

360. May 28, 1915. On surface of clayey soil, Stellenbosch Flats. (*Nostoc commune*—specimen dried up in tube.)

361. June 22, 1915. In slowly running water, Stellenbosch Flats. (*Zygnema* sp., *Scenedesmus* spp., few Desmids and Diatoms.)

362. June 22, 1915. From pool, Stellenbosch Flats. (Same as No. 361.)

363. Aug. 3, 1915. From small pool in garden, Stellenbosch. (*Spirogyra affinis*, *Tribonema bombycinum*, *Closterium acerosum*.)

364. Aug. 3, 1915. Same locality and species as No. 363.

365. Aug. 4, 1915. In ditch on side of road, near Papegaaisberg, Stellenbosch. (*Hormidium rivulare*, *Tribonema bombycinum*, *Oedogonium oblongum* f. *majus*, *Closterium Stellenboschense* sp. n., *Eunotia pectinalis*.)

366. Aug. 6, 1915. On surface of damp gravel, Stellenbosch Flats. (*Zygnema* sp., *Oedogonium* sp., *Spirogyra* sp., *Penium cruciferum*, few Diatoms.)

367. Aug. 6, 1915. In pool near old graveyard, Stellenbosch Flats. Colour pale yellow-green. (*Zygnema stellinum*, *Spirogyra catenaeformis*, *Anabaena* sp., *Microcoleus chthonoplastes*, few Desmids and Diatoms.)

368. Aug. 6, 1915. Pool on flats near Stellenbosch. (Same species as in No. 367.)

372. Aug. 10, 1915. Forming bright green felt on surface of moist soil in greenhouse, Stellenbosch. (*Vaucheria hamata*, *Hormidium flaccidum*, *Phormidium autumnale*.)

373. Aug. 11, 1915. In stone basin of fountain, Stellenbosch. Colour red. (*Sphaerella lacustris*.)

374. Aug. 22, 1915. In bubbling spring, forming large, bright green gelatinous masses, Vredenburg Estate, Stellenbosch. (*Chlamydomonas Reinhardi* (?), few Diatoms.)

375. Aug. 22, 1915. In shallow swamp, near Stellenbosch. (*Zygnema stellinum*, *Oedogonium* sp., *Closterium spinosporum*, var. *minus*, *Cosmarium scopulorum*.)

376. Oct. 20, 1915. Floating dark green mats, in ditches, Stellenbosch Flats. (*Oedogonium capillare* forma, *Aphanochaete repens*.)

377. Nov. 20, 1915. In water in neglected tins, greenhouse of Botanical Laboratory, Stellenbosch. (*Oedogonium capilliforme*, *Oedogonium* sp., *Chlorochytrium Lemnae*, *Phormidium corium*, few Diatoms.)

378. Nov. 22, 1915. On pieces of wood in river. Colour yellowish green. Stellenbosch. (*Ulothrix variabilis*.)

379. Nov. 22, 1915. On damp earth, Stellenbosch. Colour dark green. (*Oscillatoria formosa*.)

380. Nov. 25, 1915. Forming bright green patches on surface of moist porous pots in botanical greenhouse, Stellenbosch. (*Aphanothece saxicola*.)

381. (No date.) On damp earth amongst mosses, Stellenbosch. (*Zygnema capense* sp. n., *Zygnema* sp., *Ulothrix aequalis*.)

382. Dec. 2, 1915. In stagnant water, Stellenbosch. (*Stigeoclonium falklandicum*, *Chlamydomonas de Baryana*.)

389. March 7, 1916. Attached to dripping roots hanging over edge of stone fountain, Stellenbosch. Colour dark green. (*Microchaete diplosiphon*, var. *tenuis* var. nov., *Mougeotia gracillima*, *Cosmarium* spp., *Penium australe*, var. *minus*.)

390. March 7, 1916. Attached to submerged leaf-stalks of water-plant in stone fountain, Stellenbosch. (*Oedogonium* sp., *Stigeoclonium* sp., *Gomphonema* spp.)

391. March 7, 1916. Attached to edges and under-surface of floating leaf. Colour pale green. Stellenbosch. (*Oedogonium* spp., *Oe. Virceburgense*, *Uronema confervicolum*, *Stigeoclonium* sp., *Gomphonema* spp.)

392. March 7, 1916. (Same locality and species as No. 391.)

393. June 4, 1916. Floating in fresh water. Colour yellowish green. Stellenbosch. (*Oedogonium capilliforme*.)

394. July 27, 1916. Small pale green transparent globules, loosely attached to water-plants in ditch, Stellenbosch Flats. (*Vaucheria* sp., *Chlamydomonas Reinhardi*, *Navicula vulgaris*.)

403. March 24, 1918. In glass tank in laboratory, Stellenbosch. Bright green in colour. (*Tribonema bombycinum* formae, *Synedra Ulna*, var. *vitrea*.)

404. March 24, 1918. Forming a dark green felt on sides of glass tank in laboratory, Stellenbosch. (*Microchaete capensis* sp. n., *Phormidium tenue*.)

406. July 27, 1918. Bright green gelatinous layer on damp clayey soil, Stellenbosch. (*Cylindrocystis Brébissonii*, *C. crassa*, *Anabaena* sp., *Oscillatoria deflexa* forma (?), *Phormidium calidum*, *Nitzschia* spp.)

407. July 27, 1918. Bright green gelatinous layer on surface of depressions, filled with fresh water, on clayey soil. Stellenbosch Flats after rain. (Same species as in No. 406.)

409. Aug. 31, 1919. Gelatinous blue-green and reddish-brown masses, clinging to damp rocks in neighbourhood of waterfall. Mountains near Stellenbosch. (*Gloeocapsa sanguinea*, *Chroococcus minor*, *Stigonema hormoides*.)

410. July 27, 1916. In ditch, Stellenbosch Flats. Colour pale green. (*Botrydium granulatum*—specimen had dried up in tube.)

Group CHLOROPHYCEAE.

Division ISOKONTAE.

Order VOLVOCALES.

Family SPHAERELLACEAE.

Genus Sphaerella Somerf.

1. *S. lacustris* (Girod.), Wittr. in Hansg. Prodr. Algenfl. Böhmens, 1886, p. 105, fig. 52.

Diam. cell., 18–32 μ.

Sample 373 (and possibly a few cells in 352 and 353).

The preserved material showed resting-cells only, no typical ciliated cells being observed. There seems little doubt, however, that the determination is correct, since Miss Duthie reports that the water in the stone basin of the fountain, from which sample 373 was taken, turns reddish in colour after the winter rains, and contains bi-ciliated cells with distended envelopes, and also spherical resting-cells, both kinds of cells containing more or less haematochrome. Miss Duthie also sent drawings of the motile cells, which exactly resemble those of *Sphaerella lacustris*.

Family VOLVOCACEAE.

Genus Chlamydomonas Ehr.

1. *C. de Baryana*, Gorosh., Beitr. z. Kennt. d. Morph. u. System. d. Chlamydomonaden, ii, 1891, p. 9, t. 1, figs. 9–12; Wille, Algol. Not., xi, 1903, p. 141, t. 4, fig. 14.

Long. cell., 11–15 μ; lat., 7–10·6 μ.

Sample 382.

Although most of the cells had lost their cilia they were typical as regards shape, position of pyrenoid, and the hemispherical anterior wart. The first division of the cell was transverse.

2. *C. Reinhardi*, Dang., Ann. Sci. Nat., sér. 7, Bot., vii, 1888, p. 130, t. 12, figs. 28, 29; Wille, *loc. cit.*, p. 139, t. 4, fig. 9.

Long. cell., 10·5–20 μ; lat., 9–15 μ.

Sample 394.

Shape of cell broadly oval, subglobose or globose. Plane of first division transverse. No anterior wart.

Already recorded from South Africa by Fritsch (1918).

In tube 374 there was a species of *Chlamydomonas* which in form, position of pyrenoid, and shape of chloroplast exactly resembled *C. Reinhardi*, but it had a diameter of only 7–12 μ, which is smaller than the typical form of this species. It could also be compared with *C. globosa*, Snow, but was rather too large for this. Perhaps it is a form intermediate between *C. globosa* and *C. Reinhardi*, but since the material was in a very poor state of preservation (cilia were rarely observed and the presence of an eye-spot was doubtful) this point remains unsettled.

Family PROTOCOCCACEAE.

Genus Protococcus Agardh.

(=Pleurococcus auct.).

1. *P. antarcticus* (W. & G. S. West), G. S. West, Algol. Not., xix; Journ. Bot., liv, 1916, p. 2; *Pleurococcus antarcticus*, W. & G. S. West, Biol. Rep. of Brit. Antarctic Exped., 1907–9, i, pt. 7, 1911, p. 276, t. 24, figs. 49–51; Fritsch, National Antarctic Exped., Nat. Hist., vi, 1912, p. 13.

Forma *typica*, Fritsch (*loc. cit.*, 1912, p. 13, t. 1, fig. 26).

Diam. cell., 16–40 (–60) μ; crass. membr. cell., 1·3–2·5 μ.

Samples 352, 353.

The younger cells (Fig. 1, *A*) show a well-defined parietal bright green chloroplast, which is always more or less perforated, but in older cells the chloroplast is very indefinite and generally hidden by numerous angular

starch-grains (Fig. 1, *B*). Several pyrenoids (sometimes only one) are also to be made out in the younger cells, but these also are much obscured in the older cells. Most of the cells, especially the older ones, show a translucent mass of fatty matter placed eccentrically; but occasionally in very old cells the fat seemed to permeate the whole of the cytoplasm, and in such cases starch-grains were absent. Generally, however, the fat had accumulated laterally, and appeared as a more or less separate mass outside the general cytoplasm.

Reproduction was by the division of the cell-contents to form either

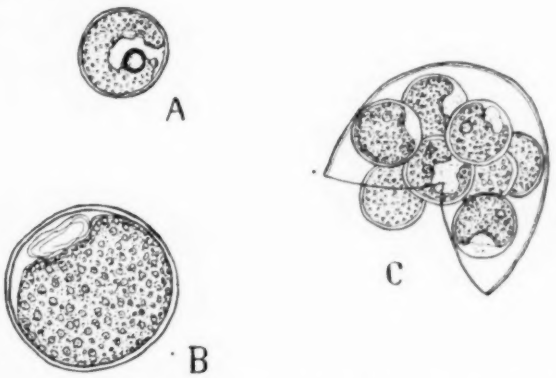


Fig. 1.—*A–C*, *Protococcus antarcticus*. *A*, Young vegetative cell, showing chloroplast and a single pyrenoid; *B*, older cell, showing numerous starch-grains in the chloroplast, and a mass of fatty material placed eccentrically outside the chloroplast; *C*, eight young daughter-cells escaping from mother-cell. *A*, *B* × 750; *C* × 600.

4 or 8 daughter-cells (Fig. 1, *C*). The cells undoubtedly attain a large size (up to 60 μ diameter) prior to cell-division. The daughter-cells acquire a cell-wall, and round themselves off before being liberated from the mother-cell, the latter process being effected by splitting of the cell-wall of the mother-cell.* Large empty cells with a split cell-wall were not infrequently seen. The daughter-cells are, of course, of the nature of autospores, and it may be noted that a similar method of reproduction has been mentioned by G. S. West (Algae, i, 1916, fig. 118, *A*) in the case of *Protococcus viridis*.

Hitherto all that was known of the method of reproduction of *P. antarcticus* was the fact of cell-division, noticed by Fritsch (Brit. Antarctic Exped., 1910, Nat. Hist. Rep. Bot., i, 1917, p. 3, t. 1, fig. 19), who observed

* In specimens of this alga brought from Greenland by Professor A. C. Seward in 1921, and submitted to the present writer, it was also observed that vegetative division was followed by the formation of four daughter-cells, produced exactly as described above.

division of the cell-contents "into two or even more parts," and gave a figure of a cell with its contents divided into two parts.

The forma *simplex* of this species has already been recorded from the Cape (Fritsch, 1918).

Family AUTOSPORACEAE.

Genus Westella Schmidle

(=Tetracoccus W. West).

1. *W. botryoides* (W. West), de Wildman, Bull. Herb. Boiss., v, 1897, p. 532; *Tetracoccus botryoides*, W. West, "Alg. English Lake District," Journ. Roy. Micros. Soc., 1892, p. 735, t. 10, figs. 43–48.

Samples 357, 358, 361, 362.

Diam. cell., 5–9 μ.

Not previously recorded from South Africa.

Genus Oocystis Nägeli.

1. *O. solitaria*, Wittr., in Wittr. and Nordst. Alg. Exsicc., No. 244; Bot. Not., 1879, p. 24.

Samples 357, 358, 367, 361.

Recorded from the Cape by Fritsch.

2. *O. lacustris*, Chodat, "Etudes de Biol. Lacustre," Bull. Herb. Boiss., 1897, p. 119, t. 10, figs. 1–7.

Sample 357 (rare).

Genus Tetraëdron Kütz.

1. *T. minimum* (Al. Braun), Hansg., Hedwigia, xxvii, 1888, p. 131.

Sample 362 (very rare).

Recorded from South-West Africa by G. S. West (1912).

2. *T. tumidulum* (Reinsch), Hansg., Hedwigia, 1889, p. 18.

Sample 368 (very rare).

Fig. 2, *A*.

Diam., 22·5 μ. Cells tetraedral, with broadly rounded angles and slightly concave sides. Cell-wall smooth, rather thick.

Not previously recorded from South Africa, although W. & G. S. West (Trans. Linn. Soc. Lond., v, pt. 2, 1895, p. 84, t. 5, fig. 20) have described a form of this species from Madagascar.

3. *T. pentaëdricum*, W. & G. S. West, *loc. cit.*, 1895, p. 84, t. 5, figs. 15, 16.

Forma angulis spinis brevissime praeditis.

Fig. 2, *B*.

Diam. cell. (cum spin.), 11 μ; long. spin., ca. 0·5 μ.

Sample 347 (very rare).

Very few individuals were seen. It appears to be a definite form or variety of *T. pentaëdricum*.

Genus SCENEDESMUS Meyen.

1. *S. obliquus* (Turp.), Kütz., Syn. Diat. Linnaea, viii, 1833, p. 609.

Samples 357, 358, 361, 362, 368.

Already recorded from the Cape by Fritsch (1918).

2. *S. dimorphus* (Turp.), Kütz., *loc. cit.*, 1833, p. 608; G. M. Smith, Monogr. *Scened.*, Trans. Wisconsin Acad., xviii, pt. 2, 1916, p. 434 (=*S. obliquus*, var. *dimorphus*, Hansgirg).

Samples 357, 358, 394.

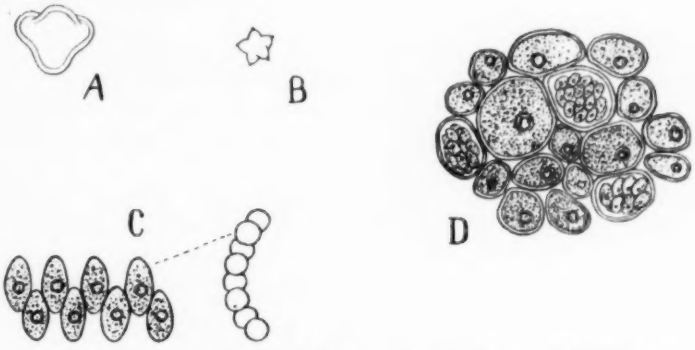


FIG. 2.—*A–D. A, Tetraëdron tumidulum*, × 520; *B, T. pentaëdricum* forma, × 500; *C, Scenedesmus arcuatus*, var. *disjunctus*, × 1500; *D, Chlorococcum olivaceum*, × 1100.

Recorded from the Cape by Fritsch (1918).

3. *S. denticulatus*, Lagerh., var. *linearis*, Hansgirg, Algenfl. v. Böhmen, 1886, p. 268.

Sample 368 (rare).

Recorded from South-West Africa by G. S. West (1912).

4. *S. serratus* (Corda), Bohlin, "La Flore Algolog. d. Acores," Bih. t. k. Sv.-Ak. Handl., **27**, Afd. iii, No. 4, 1902, p. 44, t. 1, fig. 2; Brunnthaler in Pascher, Süsswasserfl. Deutschlands, etc., Heft 5, 1915, p. 165, fig. 217.

Samples 358, 361, 363.

Apparently not previously recorded from South Africa.

5. *S. acutiformis*, Schroeder, Forschungsb. a. d. Biol. Stat. zu Plön., **5**, 1897, p. 45, t. 2, fig. 4.

Samples 357, 358, 361, 362.

Not previously recorded from the Cape.

6. *S. quadricauda* (Turp.), Bréb., var. *abundans* (Kirchn.), Lagerh.,

Öfvers Kgl. Vet.-Ak. Förh., **39**, 1882, p. 64, t. 2, fig. 20 (=*S. abundans* (Kirchn.), Chodat, var. *brevicauda*, G. M. Smith, *loc. cit.*, 1916, p. 468, t. 30, figs. 126–132).

Samples 357, 358, 362.

Already recorded from the Cape by Fritsch and Stevens (1921).

Forma *setosus* (Kirchn.), Lagerheim, *loc. cit.*, 1882, p. 63 (=*S. longus*, Meyen; G. M. Smith, *loc. cit.*, 1916, p. 469, t. 31, figs. 156–158).

Samples 358, 361.

7. *S. arcuatus*, Lemmermann, var. *disjunctus*, Borge, Bëitr. z. Algenfl. v. Schweden, iii; Arkiv. f. Bot., Bd. 18, No. 10, 1923, p. 28, fig. 1.

Long. cell., 10–17 μ; lat., 4·6–9·5 μ.

Fig. 2, *C*.

Samples 357, 361 (common), 362, 368.

Colonies usually of 8 (sometimes 4) cells. Cells more or less ellipsoidal, and often attenuated towards the extremities, as described by Borge. Occasionally the cell-wall at the apices of the cells was slightly thickened, recalling *S. arcuatus*, var. *capitatus*, G. M. Smith (Trans. Wisconsin Acad., **19**, 1918, p. 637, t. 11, figs. 4, 5), which, however, has a different form of colony.

This variety has not previously been recorded from Africa, although the typical form of the species has been recorded from Lake Tanganyika by G. S. West (1907).

Genus Ankistrodesmus Corda.

1. *A. falcatus* (Corda), Ralfs, Brit. Desm., 1848, p. 180, t. 34, fig. 3.

Sample 357.

Also recorded from the Cape by Fritsch (1918), and Fritsch and Stevens (1921).

Var. *acicularis* (Al. Br.), G. S. West, Brit. Freshwater Algae, 1904, p. 223. fig. 94, *B–C*.

Samples 357, 358, 361, 362, 366, 389, 391, 392.

Var. *spirilliformis*, G. S. West, *loc. cit.*, 1904, p. 224.

Sample 357 (very rare).

Recorded from the Cape by Fritsch (1918).

Var. *mirabilis* (W. & G. S. West), G. S. West, *loc. cit.*, 1904, p. 224, fig. 94, *E*.

Samples 357, 366.

This variety has not previously been recorded from the Cape.

Genus Coelastrum Nägeli.

1. *C. microporum*, Nägeli (in Al. Braun, Alg. Unicell., 1855, p. 70).

Samples 357, 358, 361, 362.

Recorded from the Cape by Fritsch (1918), and Fritsch and Stevens (1921).

Family PLANOSPORACEAE.

Genus Chlorococcum Fries.

1. *C. olivaceum*, Rabenhorst (Flora Europ. Algar., iii, 1868, p. 58; Brunnthaler in Pascher, Süsswasserflora Deutschlands, etc., v, 1915, p. 64).

Sample 347.

Fig. 2, *D*.

This formed an olive-green and rather slimy stratum, formed of agglutinated cells, and growing in an old water-culture. The cells were 5–11 μ diameter, variable in shape (Fig. 2, *D*), being either oval, subglobose, or angular by compression. The cell-wall was not very thick (thickness 0·5–0·8 μ), and usually was not lamellose, although very old cells had thicker and sometimes slightly lamellose cell-walls. The form of the chloroplast could not definitely be made out, but it was probably parietal, and contained a single pyrenoid, which was often angular, while small starch-grains were frequently present.

Many cells had divided to form daughter-cells, the number of which was 8 or 16 (rarely more) in each mother-cell. These daughter-cells are apparently of the nature of motile cells (zoogonidia), being ellipsoidal in shape (length, 4·5–5 μ; width, ca. 2 μ), without a definite cell-wall, and usually more or less pointed at one end, where a minute papilla (but no cilia) could sometimes be observed. Large empty cells showing a split in the cell-wall, through which presumably the zoogonidia had escaped, were frequent.

The agreement with *Chlorococcum olivaceum* seems fairly close, according to the short diagnosis of this species given by Rabenhort, and also by Brunnthaler (quoted above); but apparently there is not much known of this alga. It has not previously been recorded from South Africa.

Genus Chlorochytrium Cohn.

1. *C. Lemnae*, Cohn, Beitr. z. Biol. d. Pflanzen, i, 1874, p. 87, t. 2.

Sample 377.

Endophytic in *Lemna minor*.

Family HYDRODICTYACEAE.

Genus Pediastrum Meyen.

1. *P. duplex*, Meyen, var. *genuinum*, Al. Braun (Brunnthaler in Pascher, *loc. cit.*, 1915, p. 95, fig. 57*a*).

Sample 358 (very rare).

Already recorded from the Cape by Fritsch (1918).

Var. *clathratum* (Al. Br.), Lagerh., Öfvers. d. Kgl. Vet.-Akad. Förh., **39**, 1882, p. 56 ; Brunnthaler, *loc. cit.*, p. 95, fig. 57*d*.

The colonies were of 32 cells.

Sample 391 (very rare).

Var. *subgranulatum*, Racib. (Brunnthaler, *loc. cit.*, p. 95, fig. 57*i*).

Sample 358 (very rare).

2. *P. tetras* (Ehrenb.), Ralfs, Ann. and Mag. Nat. Hist., xiv, 1844, p. 469, t. 12, fig. 4 ; Brit. Desm., 1848, p. 182, t. 31, fig. 1.

Samples 357, 358, 387.

Already recorded from the Cape by Fritsch.

Order SIPHONALES.

Family VAUCHERIACEAE.

Genus Vaucheria D.C.

1. *V. hamata*, Walz. (Heering in Pascher, Süsswasserfl. Deutschlands, etc., vii, 1921, p. 90, fig. 81).

Sample 372.

Growing on soil in flower-pots.

Previously recorded from the Cape by Fritsch and Rich.

Sample 394 contained a species of *Vaucheria* in the vegetative condition.

Order SIPHONOCLADIALES.

Family CLADOPHORACEAE.

Genus Chaetomorpha Kütz.

1. *C. herbipolensis*, Lagerh. (Ber. Deutsch. Bot. Ges., v, 1887, p. 195, t. 9, figs. 1–10 ; Heering, *loc. cit.*, 1921, p. 18, fig. 16).

Crass. fil., 28–42·5 μ ; crass. membr. cell., 5–7·5 μ.

Sample 349 (growing in a glass water-tank).

The filaments were unbranched, and attached by an irregular basal hapteron or holdfast (Fig. 3, *A*). The cells were $1\frac{1}{3}$–3 times as long as wide, and either cylindrical or somewhat barrel-shaped (as described by Lagerheim, *loc. cit.*). The cell-wall was strongly lamellose and longitudinally striated. Small angular starch-grains filled the cells, and obscured the form of the chloroplast (Fig. 3, *B*). Empty cells (zoogonidangia) with a lateral pore in the cell-wall (exactly as figured by Lagerheim) were occasionally observed.

The agreement with *C. herbipolensis* is very close, the chief difference being the somewhat narrower filaments. The species has not previously been recorded from South Africa.

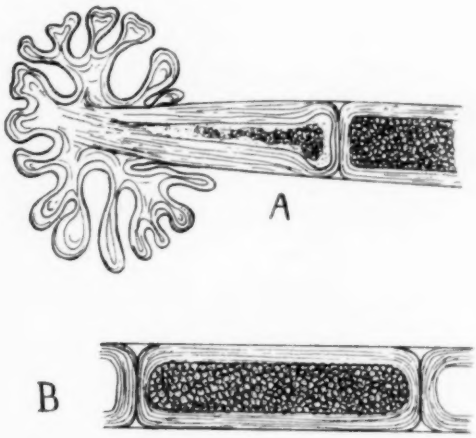


FIG. 3.—*A*, *B*, *Chaetomorpha herbipolensis*. *A*, basal cell of a filament showing the holdfast; *B*, vegetative cell, showing the thick cell-wall, and numerous angular starch-grains within the cell. *A*, *B* × 400.

ORDER ULOTRICHALES.

FAMILY ULOTRICHACEAE.

Genus HORMIDIUM Klebs.

1. *H. flaccidum*, A. Br. (Heering in Pascher, Süsswasserfl. Deutsch., etc., vi, 1914, p. 46, fig. 48).

Crass. fil., 6–7 μ.

Samples 350, 352, 372.

Already recorded from the Cape by Fritsch and Stevens (1921).

2. *H. rivulare*, Kütz., Phyc. German, 1845, p. 192; Heering, *loc. cit.*, p. 47, fig. 56.

Crass. fil., 9·3–10 (–12) μ.

Samples 358, 365.

Cell-wall thick and lamellose. Cells quadrate or subquadrate. The filaments not infrequently showed "knee-bends," as figured by Fritsch (Ann. S. Afr. Mus., ix, 1918, fig. 13*e*), who has already recorded the species from the Cape and described it fully.

Genus Ulothrix Kütz.

1. *U. variabilis*, Kütz., Spec. Algar., 1849, p. 346; Heering, *loc. cit.*, p. 32, fig. 27.

Samples 356, 359, 378.

Recorded from the Cape by Fritsch (1918), and Fritsch and Stevens (1921).

2. *U. aequalis*, Kütz., Phyc. German, 1845, p. 197; Tab. Phyc., ii, 1852, t. 29, fig. 1; Heering, *loc. cit.*, 1914, p. 35, figs. 33, 34.

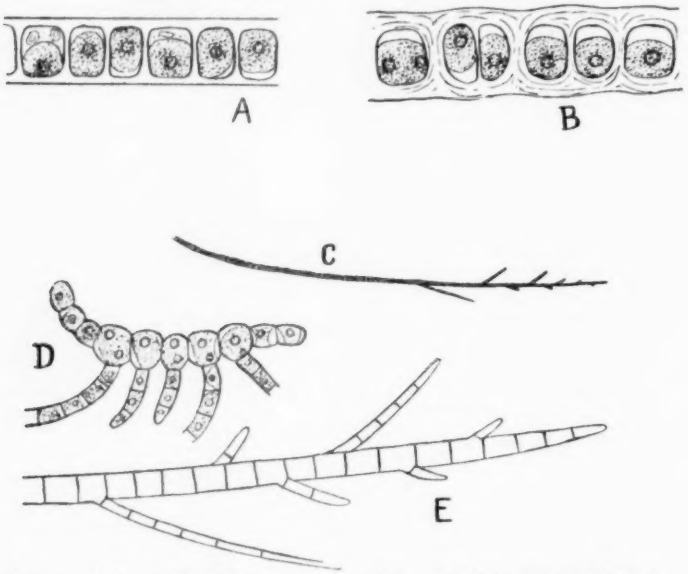


Fig. 4.—*A–E*. *A*, *B*, *Ulothrix aequalis*, × 750; *C–E*, *Stigeoclonium falklandicum*; *C*, erect filament, showing type of branching; *D*, part of creeping basal filament; *E*, apical part of an erect filament (cells in outline only). *C* × ca. 100; *D*, *E* × 650.

Crass. fil., 12·8–19·2 μ; cells $\frac{3}{4}$–$1\frac{1}{8}$ times longer than the diameter. Fig. 4, *A–B*.

Sample 381.

This alga formed long filaments, which did not readily tend to break up. In the younger filaments the cells were exactly cylindrical, but in older filaments they were more or less barrel-shaped (Fig. 4, *B*). The cells were subquadrate, but generally somewhat shorter than the diameter (half as long as wide just after cell-division). The chloroplast showed a very distinct single pyrenoid (Fig. 4, *A*, *B*).

The only other species to which this shows any marked resemblance is *U. moniliformis*, Kütz., which, however, has even the young filaments constricted at the transverse walls, while its filaments are decidedly narrower than those of *U. aequalis*. The latter has not previously been recorded from South Africa.

Genus Uronema Lagerh.

1. *U. confervicolum*, Lagerh., Notarisia, 1888, p. 597; Heering, *loc. cit.*, 1914, p. 36, fig. 37.

Crass. fil., 5–6 μ; long. cell., 10–18 μ.

Samples 391, 392 (Epiphytic on *Oedogonium*, but rare).

Recorded from South-West Africa by G. S. West (1912).

Family CHAETOPHORACEAE.

Genus Stigeoclonium Kütz.

1. *S. falklandicum*, Kütz., Tab. Phyc., iii, 1853, t. 2; Heering, *loc. cit.*, 1914, p. 71, fig. 94.

Sample 382 (growing upon a dead grasshopper in water).

The creeping basal part of the thallus was not specially developed. Many of the shorter erect filaments are quite unbranched, but the longer ones show a form of branching (Fig. 4, *C*, *E*) which appears to be characteristic. The branching itself is quite poor, the lateral branches being short and limited to the apical parts of the main erect filaments, and generally becoming more distant from each other as they are traced downwards. The lower parts of the erect filaments are always unbranched. The lateral branches are apparently never opposite.

Already recorded from the Cape by Fritsch and Stevens (1921).

In samples 390, 391 were a few filaments of a species of *Stigeoclonium* which could not be identified.

Genus Microthamnion Nägeli.

1. *M. Kützingianum*, Kütz., Spec. Algar., 1849, p. 352.

Sample 348.

Also recorded from the Cape by Fritsch (1918).

Family APHANOCHAETACEAE.

Genus Aphanochaete A. Br.

1. *A. repens*, A. Br. (Heering, *loc. cit.*, 1914, p. 128, figs. 179–182).

Samples 375, 376.

Epiphytic upon *Oedogonium*, and (in 375) a wide species of *Spirogyra*. Already recorded from the Cape by Fritsch (1918).

Division STEPHANOKONTAE.

Family OEDOGONIACEAE.

Genus Oedogonium Link.

1. *Oe. capilliforme*, Kütz., Spec. Algar., 1849, p. 367; Hirn, Acta Soc. Sci. Fennicae, xxvii, 1900, p. 107, t. 8, fig. 49.

Crass. cell. veg. (♀ fil.), 29–32 μ; altit., 2–3½ plo major.
,, ,, ,, (♂ fil.), 24–29 μ.
,, oogon., 41–48 μ; altit., 51–64 μ.
,, oosp., 38–48 μ; altit., 38–48 (–55) μ.
,, cell. antherid., 25–27 μ.

Samples 377, 393.

The shape of the oospore was frequently subellipsoidal, as described by Hirn for the typical form of this species; but subglobose (rarely globose) oospores, such as are characteristic of the forma *de Baryanum* (Chmiel.), Hirn (*loc. cit.*, p. 108), were also common. The width of the oogonia agreed with the dimensions of the typical form, rather than the forma *de Baryanum*.

Not previously recorded from South Africa.

2. *Oe. capillare* (Linn.), Kütz., Phyc. Gen., 1843, p. 255, t. 12, fig. 2, 1–10; Hirn, *loc. cit.*, p. 112, t. 11, fig. 58.

Forma oogoniis paullo longioribus.

Crass. cell. veg. (♀ fil.), 41·6 μ; altit., 1–2 plo major.
,, ,, ,, (♂ fil.), 35 μ.
,, oogon., 57·5 μ; altit., 93 μ.
,, oospore, 51–54 μ; altit., 57–64 μ.
,, cell. antherid., 29–33 μ.

Sample 376.

This most closely resembled the forma *stagnale* (Kütz.), Hirn, of *Oe. capillare*, but differed in the longer oogonia.

3. *Oe. oblongum*, Wittr., forma *majus* (Nordst.), Hirn, *loc. cit.*, p. 185, t. 29, fig. 182.

Crass. cell. veg., 8 μ; altit., 6–8 plo major.
,, oogon., 29–30·6 μ; altit., 50–52 μ.
,, oosp., 25–27 μ; altit., 34–36 μ.

Sample 365 (rare).

This agreed fairly well with Hirn's description. The forma *majus* differs from the type in having somewhat larger dimensions, and in the oospores sometimes almost completely filling the oogonia. In the present

material the oospores never quite filled the oogonia, a small free space being left above and below the oospore, as figured by Hirn for the typical form of *Oe. oblongum* (*loc. cit.*, t. 29, fig. 181). The dimensions, however, agreed with the forma *majus*. The antheridia were 1 to 3-celled, and variable in position.

The species has not previously been recorded from South Africa.

4. *Oe. Virceburgense*, Hirn, *loc. cit.*, p. 301, t. 24, fig. 128.

Crass. cell. veg., 4·8–6·5 μ ; altit., 3–5 plo major.

,, oogon., 16–20·6 μ ; altit., 18–22·5 μ.

,, oospor., 16–20 μ ; altit., 13–15 μ.

Samples 391, 392.

This agreed fairly well with Hirn's description and figure, although the oogonia were sometimes rather longer than given by this authority. No other important difference was observed. The oogonia occurred either singly or in twos or threes, and opened by means of a supra-median split. The vegetative cells were cylindrical, or slightly barrel-shaped, but never tumid at the apical end.

Not previously recorded from the Cape.

Vegetative filaments of *Oedogonium* were observed in samples 349, 357, 358, 365, 366, 375, 390, 391, 392.

Genus Bulbochaete Ag.

Vegetative filaments of a species of this genus occurred in sample 357.

Division AKONTAE.

Order CONJUGATAE.

Family ZYGNEMACEAE.

Genus Zygnema (Ag.) De Bary.

1. *Z. stellinum* (Vauch.), Ag., Syst. Alg., 1824, p. 77 ; Borge in Pascher, Süsswasserfl. Deutschlands, etc., ix, 1913, p. 36, fig. 57.

Crass. cell. veg., 20–24 μ.

Long. cell. veg., 50–96 (–110) μ.

Diam. zygosp., 30–41·6 μ.

Samples 358, 367, 368, 375.

Fig. 5, *E*.

Middle layer of zygospore-wall yellow-brown in colour, and with large scrobiculations ; outermost layer smooth and colourless. The female cells were usually swollen only on the side of the conjugation tube, in order to accommodate the zygospore, as shown in Fig. 5, *E*.

Already recorded from South Africa by Fritsch (1918).

2. Z. *capense* sp. nov. (Fig. 5, *A–C*).

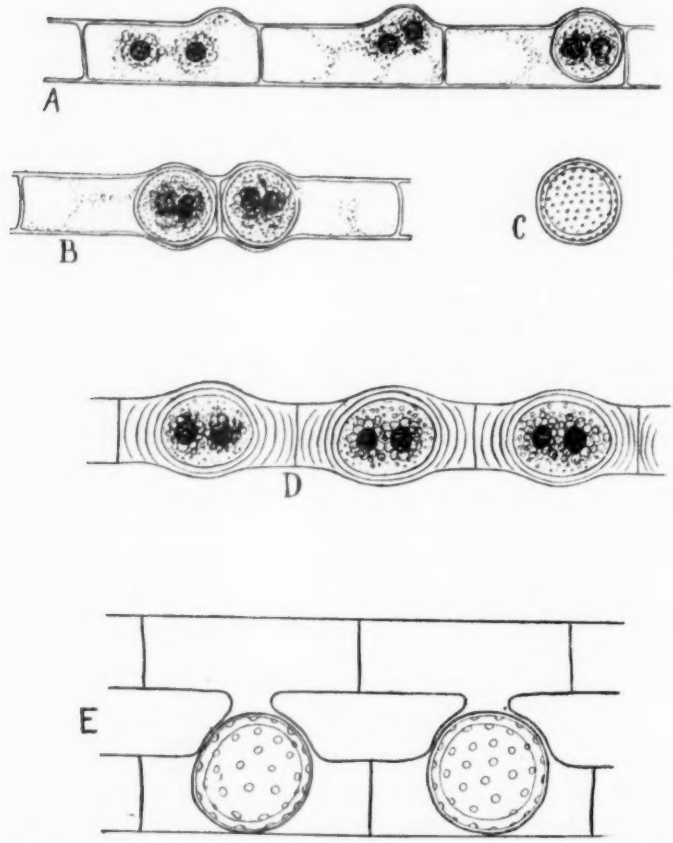


FIG. 5.—*A–E*. *A–C*, *Zygnema capense* sp. n. *A*, Three stages in the development of an aplanospore ; *B*, two adjacent aplanospores ; *C*, free aplanospore ; *A–C* × 500. *D*, *Zygnema* sp., showing akinetes, × 250. *E*, *Z. stellinum*, two zygospores, × 500.

Z. filis rectis, cellulis diametro 1½–3 plo longioribus, membrana cellularum vix incrassata ; Zygosporis ignotis ; Aplanosporis globosis, in extremitatibus paullo inflatis cellularum natis ; membrana media aplanosporae luteobrunnea scrobiculataque.

Diam. cell. veg., 16–20 μ.

Diam. aplanosp., 19–26 μ.

Sample 381 (rather rare).

Although zygospores were not observed this species seems well characterised by its aplanospores, and especially by their position in the swollen ends of the cells. The vegetative cells usually show two distinct chloroplasts of rather rounded form, each with a pyrenoid, but at times the two chloroplasts appear to be connected by a slender bridge, giving the appearance of a single axile chloroplast. The general cytoplasm of the cell has a granular appearance owing to the presence of numerous minute brownish granules. It is not clear whether these granules have been produced by the preservative present in the tube, or whether they are present in the living cell. The cell-structure to some extent recalls that of *Zygogonium ericetorum*, Kütz. (*cf.* West and Starkey, New Phytol., xiv, 1915, p. 194, etc.), a species which has a single axile chloroplast in each cell.

A cell about to produce an aplanospore first puts out a short process at one end, as though about to form a conjugation tube. The cell-contents move into the swollen part, and there becomes rounded off and surrounded by a new cell-wall (Fig. 5, *A*). A remnant of protoplasm remains in the cell—another feature recalling *Zygogonium ericetorum* (*cf.* " The Conjugation of *Zygogonium ericetorum*," Hodgetts, New Phytol., 1918, p. 238, etc.). Sometimes two adjacent cells of a filament produce aplanospores, one on each side of the separating transverse wall (Fig. 5, *B*), suggesting incipient lateral conjugation changing over to aplanospore formation. There was no evidence, however, that conjugation ever took place. Two separate pyrenoids were usually quite easily distinguished within each aplanospore. Later the wall of the aplanospore becomes brown and scrobiculate (Fig. 5, *C*), and eventually the aplanospore itself becomes free from the mother-cell upon the disintegration of the filament.

3. *Zygnema* sp. (Fig. 5, *D*).

Crass. cell. veg., 35–50 μ; diam., $\frac{1}{2}$–1 (–1$\frac{1}{2}$) plo longioribus. Crass. spor., 40–55 μ; long. spor., 65–80 μ.

Sample 381.

It is doubtful whether this species can be identified, since the only form of spore observed was of the nature of an akinete. In forming an akinete the cell-wall swells and becomes very gelatinous and lamellose, while the cell-contents contract to form an oval mass in the centre of the cell, the cell itself becoming swollen and barrel-shaped in the middle, the ends usually remaining more or less parallel (Fig. 5, *D*). The akinetes are usually produced in series, giving the filament a moniliform appearance. All intermediate stages between vegetative filaments and mature akinetes were observed. There does not appear to be any new cell-wall formed round the cell-contents, the thick investment round each

akinete being the result of the swelling and gelatinisation of the original cell-wall.

Fritsch and Stevens (Trans. Roy. Soc. S. Afr., ix, pt. 1, 1921, p. 55, fig. 25, *D–H*) have described very similar akinetes from the Cape, which they state "appear to be referable to *Z. pectinatum* (Vauch.), Ag.," although in a footnote they point out there is a possibility of them belonging to another species. In their dimensions the present akinetes do not agree with those described by these authors.

Vegetative filaments of *Zygnema* were present in samples 356, 357, 359, 361, 362, 365, 366.

Genus Spirogyra Link.

1. *S. inflata* (Vauch.), Rabenh., Borge in Pascher, Süsswasserfl. Deutschlands, etc., ix, 1913, p. 17, fig. 3.

Crass. cell. veg., 16–17 μ; crass. zygosp., 28–29 μ; long. zygosp., 54·4 μ.

Conjugation was lateral.

Sample 357 (very rare).

Recorded from Natal by Fritsch and Rich (1924).

2. *S. affinis* (Hass.), Kütz., Borge, *loc. cit.*, 1913, p. 21, fig. 19.

Crass. cell. veg., 29–32 μ; long. cell., 43–80 μ.

„ zygosp., 29–34 μ; long., 48–58 μ.

Conjugation was lateral (rarely scalariform), and exactly resembled the figures of this species given by Petit (Spir. d. Environs de Paris, 1880, t. 3, figs. 13, 14).

Samples 363, 364.

Not previously recorded from the Cape.

3. *S. catenaeformis* (Hass.), Kütz., Petit, *loc. cit.*, 1880, p. 17, t. 3, figs. 9–12; Borge, *loc. cit.*, 1913, p. 21, fig. 18.

Samples 367, 368 (very rare).

Not previously recorded from the Cape.

Vegetative filaments of *Spirogyra* were present in samples 361, 362, 366, 375.

Family MESOCARPACEAE.

Genus Mougeotia Ag.

1. *M. gracillima* (Hass.), Wittr., "Om Gotlands och Ölands sötvattensalg.," Bih. till K. Vet.-Akad. Handl., i, No. 1, 1872, p. 40; Borge, *loc. cit.*, 1913, p. 43, fig. 76.

Crass. cell., 6·5–6·7 μ; long. cell., 52–110 μ.

Diam. zygosp., 20–29 μ.

Sample 389.

The zygospores were typical of this species, being quadrate with deeply concave sides, retuse angles, and the mesosporium finely granulate.

Already recorded (in the vegetative condition) from the Cape by Fritsch (1918).

Vegetative filaments of *Mougeotia* were present in samples 356, 359.

Family DESMIDIACEAE.

Genus Gonatozygon De Bary.

1. *G. Brébissonii*, De Bary, Conj., 1858, p. 77, t. 4, figs. 26, 27; W. & G. S. West, Brit. Desm., i, 1904, p. 31, t. 1, figs. 8–11.

Samples 357, 362 (very rare).

Not previously recorded from the Cape.

Genus Cylindrocystis Menegh.

1. *C. Brébissonii*, Menegh., W. & G. S. West, *loc. cit.*, 1904, p. 58, t. 4, figs. 23–32.

Samples 381, 406, 407.

Var. *minor*, W. & G. S. West, "Alg. N. Ireland," Trans. Roy. Irish Acad., xxxii, B, pt. 1, 1902, p. 20, t. 2, fig. 7.

Long. cell., 32–42 μ; lat., 11–14 μ.

Both the type and this variety have been recorded from the Cape by Fritsch and Stevens (1921).

2. *C. crassa*, De Bary, Conjug., 1858, p. 37, t. 7, figs. *C*, 1–12; W. & G. S. West, *loc. cit.*, 1904, p. 59, t. 4, figs. 33–38.

Long. cell., 45–60 μ; crass., 24–28 μ.

Samples 406, 407 (rare).

A form rather larger than the type. W. & G. S. West (*loc. cit.*, p. 60) give the size of *C. crassa* as 22–46 μ long, and 18–24 μ wide. Cells were occasionally seen which fell within these limits, but usually this size was exceeded. Perhaps it should be regarded as a new form.

The type has been recorded from the Cape by Fritsch (1918).

Forma tenuis f. nov. (Fig. 6, *A–C*).

F. paulo tenuior quam forma typica.

Long. cell., 19–27 μ; lat. cell., 12·8–16 μ.

Sample 381 (rather rare).

This should probably be considered as a narrow form of *C. crassa*. The chloroplasts are substellate. The general shape of the cell resembles *C. crassa* rather than *C. Brébissonii* f. *minor*, the latter being relatively longer than the present form. The only real difference from the typical form of *C. crassa* is the narrower width of the cells. Frequently, especially in young individuals, one end of the cell was rather broader than the other,

and sometimes also more or less truncate (as shown in Fig. 6, *B*, *C*), a condition which has also been noticed in the typical form of *C. crassa* by Fritsch (Ann. of S. Afr. Mus., ix, pt. 7, 1918, p. 541, fig. 20, *A*).

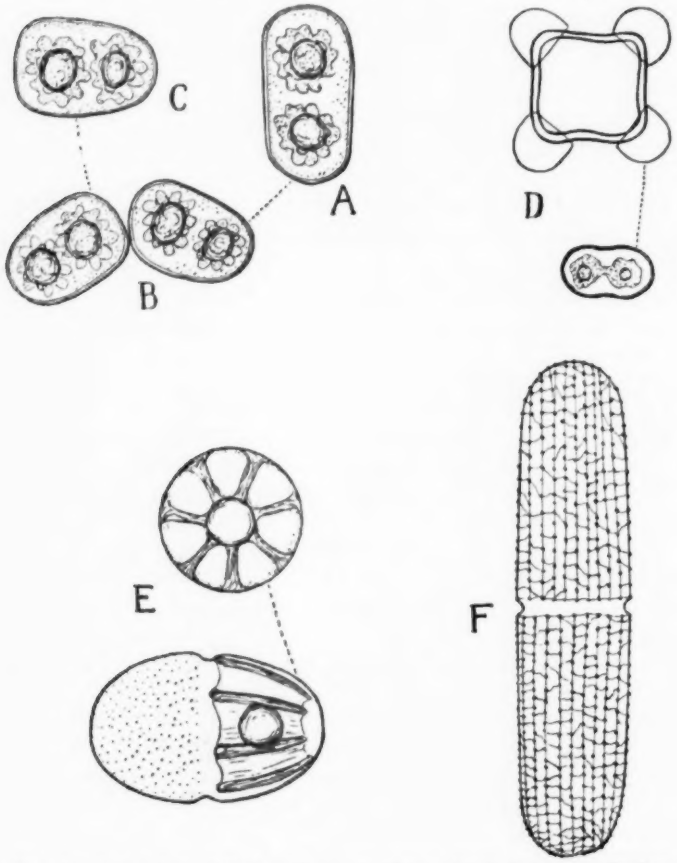


FIG. 6.—*A–F*. *A–C*, *Cylindrocystis crassa*, forma *tenuis* f. n.; *D*, *Penium minutissimum*, zygospore, and a vegetative cell; *E*, *P. australe*, var. *minus* var. nov.; *F*, *P. costatum* sp. n. *A–E* × 1000; *F* × 750.

Genus PENIUM Bréb.

1. *P. Libellula* (Focke), Nordst., var. *intermedium*, Roy and Biss., W. & G. S. West, *loc. cit.*, 1904, p. 74, t. 7, fig. 11.

Samples 357, 358 (very rare).

Not previously recorded from the Cape.

2. *P. minutissimum*, Nordst., Norges Desm., 1873, p. 43, t. 1, fig. 21; W. & G. S. West, *loc. cit.*, 1904, p. 81, t. 8, figs. 20–23.

Long. cell., 13–13·5 μ; lat., 8–9 μ.

Sample 365 (very rare).

A few zygospores were seen (Fig. 6, *D*), their shape being subquadrate with slightly prominent corners, to which were attached the empty semicells. The wall of the zygospore was smooth and of a brownish tint.

Not previously recorded from the Cape.

3. *P. cruciferum* (De Bary), Wittr., in Wittr. and Nordst., Alg. Exsicc., 1882, No. 482; W. & G. S. West, *loc. cit.*, 1904, p. 100, t. 10, figs. 18, 19.

Long. cell., 14–17 μ; lat., 7·3–8 μ.

Cells either unconstricted, or with a slight median constriction.

Sample 366.

Not previously recorded from the Cape.

4. *P. cylindrus* (Ehrenb.), Bréb., W. & G. S. West, *loc. cit.*, 1904, p. 84, t. 6, figs. 1–3.

Long. cell., 34·6 μ; lat., 10·6 μ.

Cell-wall brownish, and with uniformly scattered granules as figured by W. & G. S. West (*loc. cit.*, fig. 2).

Not previously recorded from the Cape.

5. *P. australe*, Racib., Rosprawy Akad. Umiej. Krakow. Wydziat nat. przyn., sér. 2, xxii, 1892, p. 367, t. 6, fig. 27; W. & G. S. West, Desm. from Singapore, Journ. Linn. Soc. Bot., xxxiii, 1897, p. 157, t. 8, fig. 16.

Var. MINUS var. nov. (Fig. 6, *E*).

Long. cell., 35–39 μ; lat., 22·4–24 μ; lat. isthm., 19–21·5 μ.

Samples 389, 390, 391.

This agrees in shape with *P. australe*, especially with the "forma brevior," W. & G. S. West (Journ. Linn. Soc. Bot., xxxviii, 1907, p. 108, t. 6, fig. 3), but is much smaller, and has, therefore, been considered as a new variety. The chloroplast is exactly that of a *Penium* rather than a *Cosmarium*, having seven very regular longitudinal ridges which tend to broaden out near the cell-wall. The cell-wall is colourless and punctate. It can also be compared with *Cosmarium Cucurbita*, var. *attenuatum*, G. S. West (W. & G. S. West, Brit. Desm., iii, 1908, p. 108, t. 73, figs. 34–36), which, however, is relatively narrower, and has the semicells more attenuated towards the apices. Also, according to W. & G. S. West, *C. Cucurbita* has an axile chloroplast with "several very irregular ridges."

6. P. COSTATUM sp. nov. (Fig. 6, *F*).

P. cellulis cylindraceis diametro 4–5 plo longioribus, in medio modice constrictis, utrinque levissime attenuatis, apicibus late rotundatis;

membrana brunneola, costis longitudinalibus granulatis praedita ; granulis costis transversalibus vel plus minusve irregularibus connexis.

Long. cell., 96–105·3 μ ; lat. bas. semicell., 22–24 μ ; lat. apic., 16–18 μ ; lat. isthm., 18–21·3 μ.

Sample 358 (very rare).

The cell-wall is brownish in colour, and furnished with longitudinal granulate ridges (10–11 ridges visible across the cell), the granules being placed at irregular intervals. These longitudinal ridges are connected at irregular intervals by numerous rather finer transverse ridges, each of the latter running from a granule on one ridge to another granule on an adjacent longitudinal ridge, and running either exactly transversely or rather obliquely. At the apex of each semicell the anastomosing ridges become more irregular. The isthmus is free of granules and ridges.

In each semicell is an axile chloroplast with longitudinal ridges (number not determined), and with three pyrenoids, while towards the apex of the semicell is a large vacuole, which (in the living cell) may perhaps contain a few moving granules. The size of the cells, the colour of the cell-wall, and the distribution of the granules recall *P. margaritaceum* (Ehr.), Bréb., but the peculiar ridges on the cell-wall at once distinguish the present species. Very few individuals were seen, as it was very rare.

Genus Closterium Nitzsch.

1. *C. juncidum*, Ralfs, Brit. Desm., 1848, p. 172, t. 29, fig. 6 ; W. & G. S. West, *loc. cit.*, i, 1904, p. 128, t. 14, figs. 10–14.

Sample 357, 358 (very rare).

2. C. spinosporum sp. nov. (Fig. 7, *A*, *B*). Cl. valde curvatum, cellulis diametro 10–11 plo longioribus, ventre non inflato (raro leviter inflato), utroque polo gradatim attenuatis, apicibus oblique truncatis ; membrana cellularum luteola vel achroa, glabra, ad extremitates cellularum incrassata ; singulae chromatophorae pyrenoidibus 3–4 instructae ; locellus apicalis granulis 3–5 praeditus.

Zygospora subglobosa, spinis conicis brevibus obtusis instructa.

Crass. cell., 10·6–13 μ ; apic., 120–129 μ inter se distantibus ; lat. apic., ca. 2·5 μ. Diam. zygosp. (cum spin.), 27–31 μ ; long spin., 2·6–4 μ.

Samples 357, 358.

The cells of this species exactly resemble a small form of *C. Dianae*, Ehr., and like this species the apices are obliquely truncated, and have the cell-wall at the apex slightly thickened. *C. Dianae*, however, has smooth zygospores. Another species which it appears to resemble closely is *C. paradoxum*, Wille (Bidrag til Kundskaben om Norges Ferskvandsalg., i, Vidensk.-Selsk. Forhandl., Christiania, 1880, No. 11, p. 56, t. 2, fig. 37).

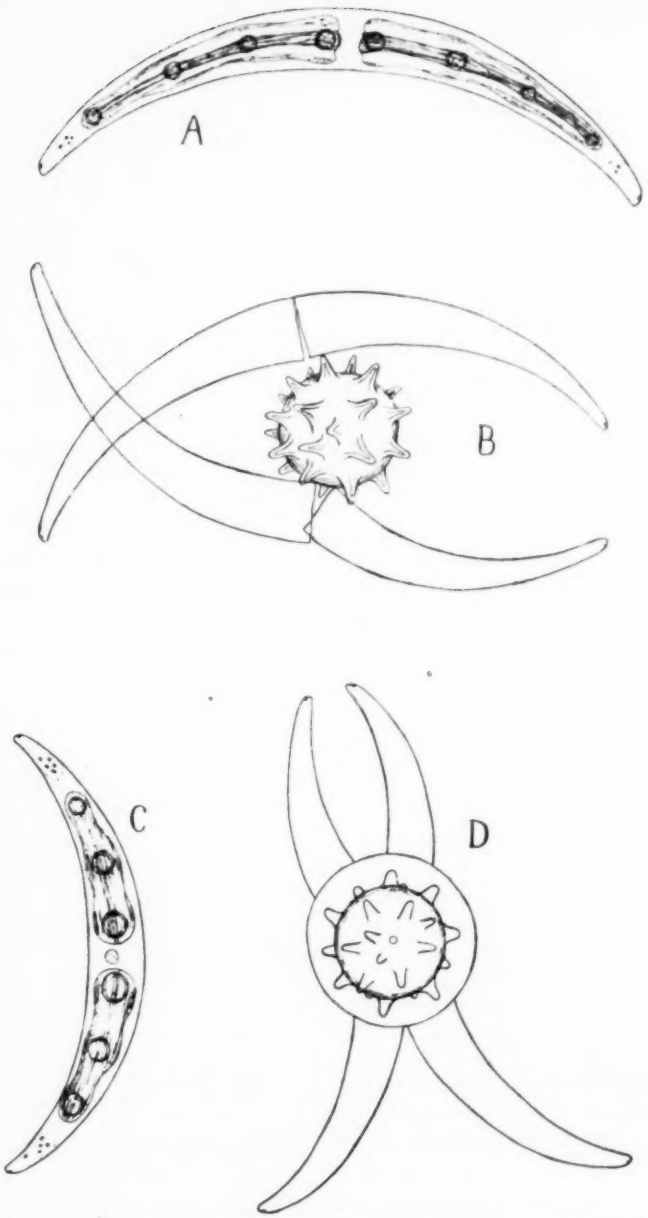


FIG. 7.—*A–D.* *A, B, Closterium spinosporum* sp. n. *A,* vegetative cell; *B,* zygospore. *C, D, C. spinosporum,* var. *minus* var. n. *C,* vegetative cell; *D,* zygospore. All × 750.

The dimensions of the latter are exactly those of the present species, and the cells are said to resemble those of *C. Dianae*, but the zygospore (immature) is described by Wille as globose with a verrucose cell-wall. It seems very doubtful, however, whether the zygospore of *C. paradoxum*, as figured by Wille, would ever develop the conical spines of that of the present species. Apart from the zygospores there is nothing to distinguish these two species. It seems best, however, to keep them distinct until more is known about *C. paradoxum*.

Var. MINUS var. nov. (Fig. 7, *C*, *D*).

Var. minor, cellulis diametro 7½ plo longioribus; cetera ut in forma typica.

Crass. cell., 11–11·5 μ; apic., 87–89 μ inter se distantibus; lat. apic., ca. 3·5 μ.

Diam. zygosp. (cum spin.), 23–33 μ.

,, ,, (sine spin.), 19–26 μ.

Long. spin., 3·2 μ.

Sample 375 (rare).

The zygospore of this variety was always found enclosed in a vesicle, which was dark brown in colour, and rather opaque, and to which the empty semicells remained attached (Fig. 7, *D*). The zygospore was rather more globose than that of the typical form of *C. spinosporum*, but had the same obtusely conical spines. A somewhat similar form of zygospore is found in *C. calosporum*, Wittr., a species which, however, has the apices of the vegetative cells very pointed, and does not possess the apical thickening of the cell-wall.

3. *C. Jenneri*, Ralfs, Brit. Desm., 1848, p. 167, t. 28, fig. 6; W. & G. S. West, *loc. cit.*, i. 1904, p. 134, t. 15, figs. 23–25.

Samples 361, 365 (very rare).

4. *C. incurvum*, Bréb., Liste Desm., 1856, p. 150, t. 2, fig. 47; W. & G. S. West, *loc. cit.*, p. 136, t. 15, figs. 28–30.

Long. cell., 57–61 μ.

Some individuals were seen with only one pyrenoid in each chloroplast, but otherwise typical.

Samples 358, 361, 362 (very rare).

5. C. STELLENBOSCHENSE sp. nov. (Fig. 8, *A–C*).

Cl. valde curvatum; cellulis diametro 6–7½ plo longioribus, ventre leviter inflato, utroque polo gradatim attenuatis, apicibus oblique truncatis; membrana cellularum glabra, pallide lutea vel achroa, ad extremitates cellularum leviter incrassata; quaeque chromatophora brevis, dimidiam fere partem semicellulae supplens, pyrenoidibus 2 (perraro 3) instructa; locellus apicalis granulis singulis praeditus.

Zygospora oblongo-quadrangularis, angulis rotundatis et leviter productis,

lateribus brevioribus retusis, lateribus longioribus medio inflatis; membrana zygosporae levis, achroa.

Crass. cell., 11·3–15 μ; apic., 84–113 μ inter se distantibus; lat. apic., ca. 2·6 μ.

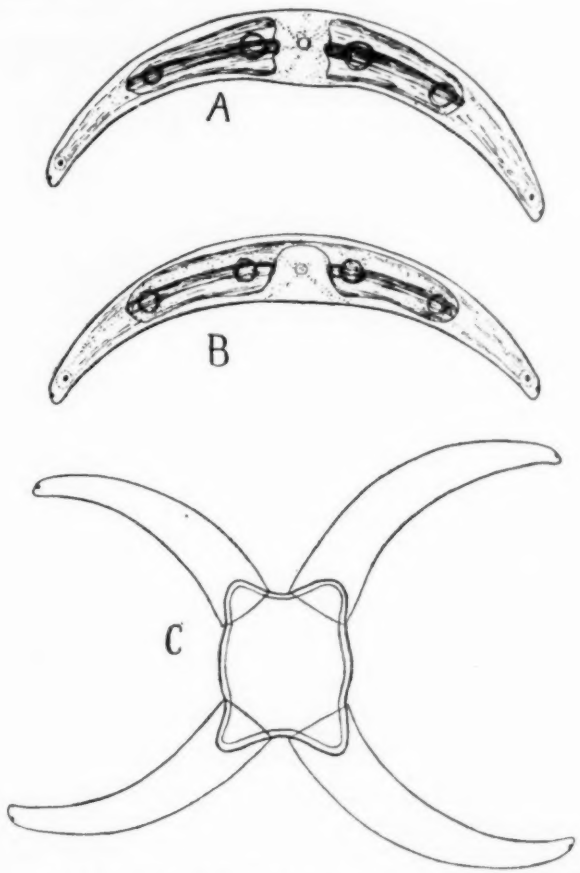


FIG. 8.—*A–C, Closterium Stellenboschense* sp. nov. *A, B,* vegetative cells. *C,* zygospore. All × 750.

Long. zygosp., 33–36 μ; lat., 25–29 μ.

Sample 365 (rare).

The only other species of *Closterium* with a zygospore of this form (Fig. 8, *C*) is *C. Venus,* Kütz., a species which not only has smaller

zygospores, but which differs in several respects from the present species in its vegetative characters. *C. Venus* has the cells much more attenuated towards the extremities, and the latter are narrower, more pointed, and lack the oblique truncation and the apical thickening of the cell-wall of the present species. The cells of *C. Stellenboschense* are also larger than those of *C. Venus*, and also differ in having the ventral margin inflated in the middle.

The short chloroplasts, each occupying only about half the length of a semicell, leaving a considerable space towards each end of the cell, are quite a feature of the present species. The terminal region is occupied mainly by cytoplasm, and not entirely by the terminal vacuole, which is comparatively small and has only one granule (Fig. 8, *A*, *B*). Several individuals were seen in which the two chloroplasts were not completely separated in the middle, but were connected by a narrow lateral bridge of chloroplast material (Fig. 8, *B*). This condition has been observed occasionally in other species of the genus, and occurs more frequently in the allied genus *Roya* (*cf.* Hodgetts, "*Roya anglica*," Journ. Bot., lviii, 1920, pp. 65–69).

6. *C. moniliferum* (Bory), Ehrenb., W. & G. S. West, *loc. cit.*, p. 142, t. 16, figs. 15, 16.

Sample 362 (very rare).

Already recorded from South Africa by Fritsch.

7. *C. acerosum* (Schrank), Ehrenb., W. & G. S. West, *loc. cit.*, p. 146, t. 18, figs. 2–5.

Samples 363, 364, 366.

In sample 363 a few zygospores were seen (diam. 79 μ, with a smooth colourless wall).

Already recorded from South-West Africa by G. S. West (1912), and from South Africa by Fritsch (1918) and Fritsch and Stevens (1921).

8. *C. praelongum*, Bréb., forma *brevior*, W. West; W. & G. S. West, *loc. cit.*, 1904, p. 165, t. 2], figs. 3–5.

Sample 362 (very rare).

Not previously recorded from the Cape.

9. *C. acutum* (Lyngb.), Bréb.

Var. *Linea* (Perty), W. & G. S. West, *loc. cit.*, 1904, p. 178, t. 23, fig. 15.

Long., 73–90 μ; lat., 4·6 μ.

Samples 361, 362, 366.

Not previously recorded from the Cape.

10. *C. Kützingii*, Bréb., W. & G. S. West, *loc. cit.*, 1904, p. 186, t. 25, figs. 6–11.

Sample 357 (very rare).

Not previously recorded from the Cape.

Genus PLEUROTAENIUM Näg.

1. *P. eugenum* (Turn.), W. & G. S. West.

Var. CAPENSE var. nov. (Fig. 9, *A*).

Var. cellulis diametro 14–15 plo longioribus, leviter attenuatis, semicellulis basi inflatis, supra partem basalem leviter 2-undulatis; tuberculis apicalibus a fronte visis 8–9; membrana cellularum regulariter et minute punctata.

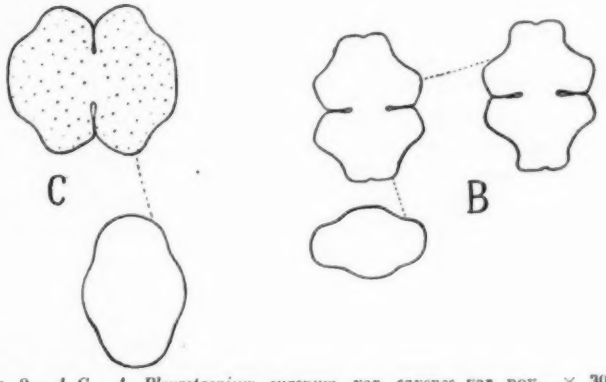


FIG. 9.—*A–C*. *A*, *Pleurotaenium eugenum*, var. *capense* var. nov., × 300; *B*, *Cosmarium scopulorum*, × 1000; *C*, *Cos. pseudosexangulare* sp. n., × 1000.

Long. cell., 480–538 μ; lat. ad bas. semicell., 34·6–35 μ; lat. ad apic., 24–25·5 μ.

Samples 357, 358 (very rare).

Differs from the usual forms of *P. eugenum* in showing only 8 or 9 elongate granules across the apex, and in the smaller size of the cells, in the two faint undulations above the larger basal one, and in the regular punctulation of the cell-wall (Fig. 9, *A*).

G. S. West has described a form of *P. eugenum* ("Contributions to our Knowledge of Freshwater Algae of Columbia," Mem. de la Soc. Neuchâteloise d. Sci. Nat., 1914, p. 1032, t. 23, fig. 62), with the same number of apical

granules as the present variety, but with the cells larger in size, and with the semicells 4-undulate at the base. The regular punctulation of the cell-wall shown by the present form appears to be unusual in *Pleurotaenium*.

Genus Tetmemorus Ralfs.

1. *T. laevis* (Kütz.), Ralfs, Brit. Desm., 1848, p. 146, t. 24, fig. 3.

Sample 375 (very rare).

Not previously recorded from the Cape.

Genus Cosmarium Corda.

1. *C. tinctum*, Ralfs, Brit. Desm., 1848, p. 95, t. 32, fig. 7.

Samples 357, 375.

Not previously recorded from the Cape.

2. *C. scopulorum*, Borge, Beitr. z. Algenfl. v. Schweden, iii; Archiv f. Bot., Bd. 18, No. 10, 1923, p. 12, t. 1, fig. 14.

Long. cell., 18·7–22·6 μ; lat. cell., 16–18 μ; lat. isthm., 4·5–5 μ (Fig. 9, *B*).

Sample 375 (rare).

This resembled those forms of *C. scopulorum*, described by Borge, which had the apices more or less retuse in the middle.

Not previously recorded from the Cape.

3. *C. bioculatum*, Bréb., var. *hians*, W. & G. S. West, "Alg. S. England," Journ. Roy. Micros. Soc., 1897, p. 486, t. 6, fig. 24; Brit. Desm., ii, 1905, p. 166, t. 61, figs. 10, 11.

Samples 367, 368 (very rare).

Not previously recorded from the Cape.

4. C. pseudosexangulare sp. nov. (Fig. 9, *C*).

C. parvum, paullo longius quam latum, profunde constrictum, sinu lineari, extremo ampliato; semicellulae late hexagone angulis rotundatis, marginibus lateralibus inferioribus subrectis et divergentibus, marginibus lateralibus superioribus retusis; apicibus rotundato-truncatis; semicellulae a vertice visae ellipticae polis rotundatis, in medio utrobique leviter inflatae, a latere visae subcirculares; membrana cellularum punctato-scrobiculata, punctis distantibus.

Long. cell., 25·6 μ; lat. cell., 23 μ; lat. isthm., 7·3 μ; crass., 16 μ.

Samples 357, 362 (very rare).

This shows considerable resemblance to *C. hammeri*, var. *africanum*, Fritsch (Trans. Roy. Soc. S. Afr., ix, pt. 1, 1921, p. 30, fig. 11, *B*), but differs in having the lower lateral margins of the semicells almost straight and divergent. The end-views of the two are almost identical.

The present species also somewhat resembles *C. sexangulare*, forma *minima*, Nordst. (W. & G. S. West, *loc. cit.*, 1905, p. 82, t. 72, figs. 4, 5), especially in the form of the upper lateral margins, but differs in not having a retuse apex.

The end-view of *C. pseudosexangulare* differs from that of *C. sexangulare* in having a median tumour on each side.

5. *C. capense*, de Toni, forma *minor*, W. & G. S. West, "Some Desm. of the United States," Journ. Linn. Soc. Bot., xxxiii, 1898, p. 301, t. 17, fig. 3.

Long. cell., 54–66 μ; lat. cell., 35–45 μ; lat. isthm., 14–16 μ.

Sample 357.

Two small forms of *C. capense* have been described, namely, (1) the above forma *minor*, W. & G. S. West ("long., 64 μ; lat., 46 μ; lat. isthm., 16 μ"), and (2) a var. *minor*, Fritsch (Ann. of the S. Afr. Mus., ix, pt. 7, 1918, p. 550, fig. 26), the size of the latter being given as long., 45–54 μ; lat., 33–36 μ; lat. isthm., 11–12 μ.

The dimensions of the present individuals tend to lie between these two forms, although including the size given by W. & G. S. West for their "forma *minor*." A few individuals were seen which might be placed in the var. *minor*, Fritsch, except that they had a rather wider isthmus. It is obvious, therefore, that the forma *minor*, W. & G. S. West, and the var. *minor*, Fritsch, merge into each other, and should be considered as a single variety of *C. capense*. The present form had the characteristic shape of the var. *minor*, Fritsch, the semicells in side view having almost parallel sides, while the end view was elliptic. The cell-wall was densely scrobiculate-punctate.

6. *C. tetragonum* (Näg.), Archer, forma *punctata* f. n. *Forma* ad var. *Davidsonii* (Roy & Biss.), W. & G. S. West (Brit. Desm., iii, 1908, p. 20, t. 66, figs. 25, 26), accedens, sed membrana punctata instructa.

Long. cell., 30 μ; lat., 20·6 μ; lat. isthm., 11 μ; crass., 15 μ (Fig. 10, *F*).

Sample 366 (very rare).

This agreed exactly in shape with the var. *Davidsonii*, but was rather smaller in dimensions, and the cell-wall was uniformly punctate. The punctulations are scattered in the centre of the semicells (in front view), but tend to have a slight radial arrangement towards the periphery.

7. *C. rectangulare*, Grun., W. & G. S. West, *loc. cit.*, iii, p. 54, t. 70, figs. 1, 2.

Forma apicibus in medio leviter retusis.

Long. cell., 22·7 μ; lat., 16–17 μ; lat. isthm., 5·5 μ.

Sample 366 (rare).

This is the form described by Fritsch (Ann. of the S. Afr. Mus., ix, pt. 7, 1918, p. 555, fig. 28, *c*) from the Cape. The end and side views were

those characteristic of the typical form of *C. rectangulare*. The retuse apex was a constant feature in all the individuals seen.

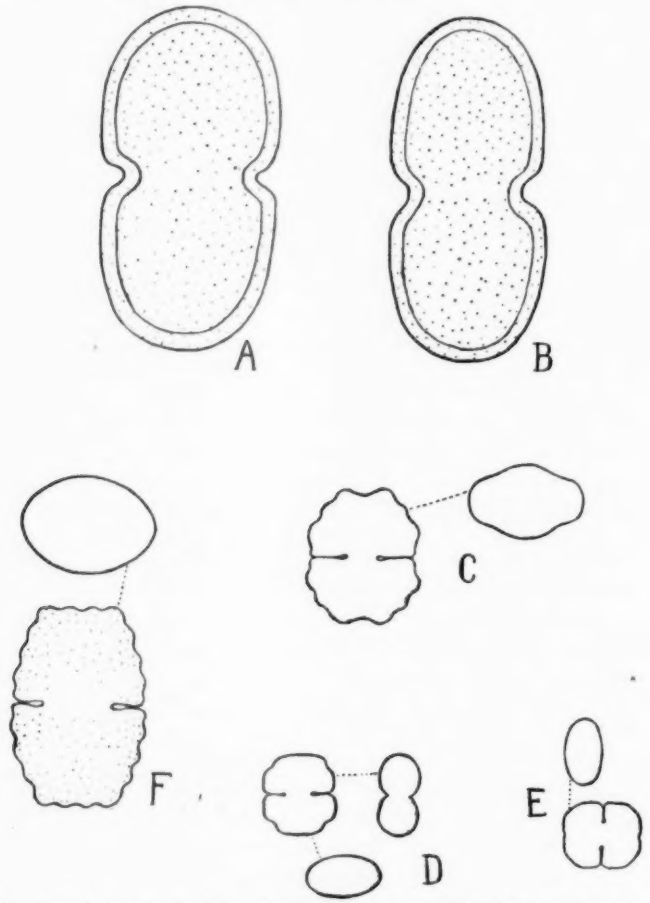


Fig. 10.—*A–F*. *A*, *B*, *Cosmarium quadratum*, var. *Willei*, forma *punctata*. *A*, front view; *B*, side view. *C*, *Cos. impressulum* forma; *D*, *E*, *Cos. angulosum*, var. *concinnum* formae; *F*, *Cos. tetragonum*, forma *punctata*. *A*, *B* × 750; *C–F* × 1000.

8. *C. quadratum*, Ralfs, var. *Willei* (Schmidle) (=*C. quadratum*, forma *Willei*, W. & G. S. West, *loc. cit.*, iii, p. 59, t. 87, figs. 21, 22).

Forma *punctata* f. nov. (Fig. 10, *A*, *B*).

F. membrana crassa et punctata.

Long. cell., 69 μ; lat., 34·7 μ; lat. isthm., 27 μ; crass, 30·6 μ.

Sample 365 (very rare).

This is a punctate form of *C. quadratum*, forma *Willei*, W. & G. S. West. The latter, however, appears to be much better considered as a variety rather than a form, and this change in the nomenclature has been made. The present form has the same straight or slightly convex sides to the semicells as the var. *Willei*, as figured by W. & G. S. West. Each semicell contained two very distinct stellate chloroplasts, each with a pyrenoid.

9. *C. polygonum* (Näg.), Archer, W. & G. S. West, *loc. cit.*, iii, p. 76, t. 71, figs. 32–34.

Sample 357.

Not previously recorded from the Cape.

10. *C. impressulum*, Elfv., W. & G. S. West, *loc. cit.*, iii, p. 86, t. 72, figs. 14–18.

Sample 361, 369 (very rare).

The following form of this species occurred in sample 357, but was rare :—

Forma semicellulis inflatione mediana praeditis.

Long. cell., 20·8 μ; lat., 17 μ; lat. isthm., 4·5 μ; crass., 11·2 μ (Fig. 10, *C*).

It differs from the type in the semicells, having a slight median tumour, as shown in Fig. 10, *C*. It may possibly be a form of *C. suborthogonum* Racib., a species which according to W. & G. S. West (*loc. cit.*, p. 86) is probably only a form of *C. impressulum*, differing from this in the end view showing a slight median swelling on each side.

11. *C. Meneghinii*, Bréb., in Ralfs' Brit. Desm., 1848, p. 96, t. 15, fig. 6; W. & G. S. West, *loc. cit.*, iii, p. 90, t. 72, figs. 29–32.

Samples 357, 358, 361.

Already recorded from the Cape by Fritsch and Stevens (1921).

12. *C. angulosum*, Bréb., var. *concinnum* (Rabenh.), W. & G. S. West, *loc. cit.*, iii, p. 94, t. 72, figs. 37, 38.

Forma angulis superioribus retusis (Fig. 10, *D*).

Long. cell., 12 μ; lat., 10·6–11 μ; lat. isthm., 4 μ.

Sample 389 (very rare).

This resembles the form figured by Borge (Algenfl. des Tåkernsees, 1921, p. 18, t. 1, fig. 14), and also by Printz (Chloroph. Norwegen, 1915, p. 26, t. 3, figs. 56, 57).

The following is another form which occurred in sample 375 (very rare) :—

Forma apicibus in medio leviter retusis (Fig. 10, *E*).

Long. cell., 12 μ; lat., 10 μ; lat. isthm., 3·5 μ.

It differs from the typical var. *concinnum* only in the truncate apex, being slightly retuse in the middle.

13. *C. laeve*, Rabenh., var. *septentrionale*, Wille, Ferskv. Alg. Nov. Semlj., 1879, p. 43, t. 12, fig. 34; W. & G. S. West, *loc. cit.*, iii, p. 102, t. 73, figs. 22–25.

Sample 357 (very rare).

Already recorded from South Africa by Fritsch (1918).

14. *C. reniforme* (Ralfs), Archer, W. & G. S. West, *loc. cit.*, iii, p. 157, t. 79, figs. 1, 2.

Samples 357, 358.

Var. *compressum*, Nordst., Bot. Not., 1887, p. 159; W. & G. S. West, *loc. cit.*, iii, p. 158, t. 79, figs. 3, 4.

Samples 358, 362 (very rare).

Not previously recorded from the Cape.

15. C. PSEUDOPRAEMORSUM sp. nov. (Fig. 11, *A*).

C. parvum, paulo longius quam latum, profunde constrictum, sinu lineari extremo ampliato; semicellulae truncato-pyramidatae, angulis inferioribus valde rotundatis, lateribus leviter convexis, apicibus late subtruncatis; membrana granulis acutis concentrice digestis ornata, granulis ad apicem multo minoribus vel nullis; serie granulorum 4 vel 5 supra isthmum praedita; semicellulae tumoribus centralibus binis 4-granulatis instructis, granulae tumorum elongatae et cruciate dispositae; semicellulae a vertice visae ellipticae ad medium utrobique tumoribus binis praeditae, a latere visae subglobosae; chromatophorae singulae in semicellula unaquaque, pyrenoide instructae.

Long. cell., 28 μ; lat., 24–27 μ; lat. isthm., 8–9 μ; crass., 15–17 μ.

Sample 357 (very rare).

Apart from the two small tumours in the centre of each semicell, this species closely resembles a small form of *C. praemorsum*, Bréb. The four granules of each tumour were usually elongated (rarely rounded) and cruciately arranged. There was a row of four or five granules placed transversely just above the isthmus. The apex of the semicell was either free of granules, or had the latter much reduced in size.

It may be compared with *C. subturpinii*, Borge (Algenfl. des Tåkernsees, 1921, p. 20, t. 1, fig. 17), which, however, is much larger, and possesses binate central tumours which have large and more or less concentrically arranged granules; and the apex of the semicell is granulate.

16. *C. punctulatum*, Bréb., W. & G. S. West, *loc. cit.*, iii, p. 206, t. 84, figs. 13, 14.

Samples 361, 375 (very rare).

Previously recorded from the Cape by Fritsch (1918) and Fritsch and Stevens (1921).

17. *C. Fritschii* sp. nov. (Fig. 11, *B*).

C. parvum, diametro $1\frac{1}{10}$ plo longioribus, profunde constrictum, sinu

lineari extremo ampliato; semicellulae truncato-pyramidatae, angulis inferioribus valde rotundatis, granulis acutis tribus instructis, angulis superioribus rotundatis granulo acuto singulo vel granulis binis instructis; lateribus biundulatis, in medio granulo acuto praeditis; apicibus levissime convexis; seriebus duabus granulorum intra marginem, serie granulorum

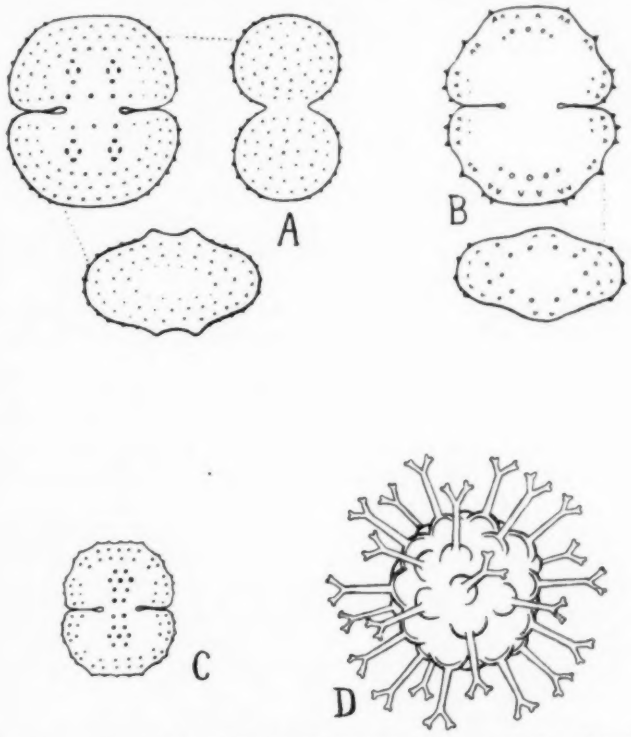


Fig. 11.—*A–D. A, Cosmarium pseudopraemorsum* sp. n.; *B, Cos. Fritschii* sp. n.; *C, D, Cos. Boeckii,* forma *minor. C,* vegetative cell; *D, zygospore.* All × 1000.

4 vel 5 supra medium semicellulae instructae; medio semicellularum levi; a vertice visae ellipticae ad medium utrobique subtumidae, granulis concentrice digestis praeditae, in centro leves; a latere visae subglobosae; chromatophora singula in semicellula unaquaque, pyrenoide instructa.

Long. cell., 28·8–29 μ; lat., 25·6 μ; lat. isthm., 6·4–8 μ; crass., 14·4 μ.

Samples 357, 358, 362 (very rare in each).

This does not appear to resemble very closely any known species,

although it can be compared in some respects with *C. tazichondrum*, var. *subundulatum*, Boldt, forma *subdenticulatum*, W. & G. S. West (" Alg. Madagascar," Trans. Linn. Soc. Lond., v, 1895, p. 67, t. 7, fig. 4). The acute granules are quite absent from the centre and also from the apex of the semicell (Fig. 11, *B*). The four or five acute granules which form an arc above the centre of each semicell are sometimes rather larger than those elsewhere.

18. *C. Boeckii*, Wille, Norges Ferskvandalg. Christiania Vidensk.-selsk. Forhandl., 1880, No. 11, p. 28, t. 1, fig. 10; W. & G. S. West, *loc. cit.*, iii, p. 234, t. 86, figs. 26–32.

Forma *minor* f. n. (Fig. 11, *C*, *D*).

Long. cell., 19–20·6 μ; lat., 16–17·5 μ; lat. isthm., 4·7–5·5 μ.

Diam. zygosp. sine spin., 24 μ.

" " cum spin., 43–44 μ.

Samples 357, 358.

The granules of the central tumour were rather variable. A frequent arrangement, however, was that shown in Fig. 11, *C*, two granules being placed transversely just above the isthmus, and above these a circle of six granules round a central one. Some of these granules of the central tumour were often duplicated. The individuals were always decidedly smaller than the dimenions given by W. & G. S. West (*loc. cit.*), but the semicells had the incised crenate margins and the undulate-nodulose apex characteristic of the species. In sample 357, zygospores of this desmid, often with the four empty semicells attached, were not uncommon. There appears to be no previous record of the zygospore of *C. Boeckii*. They were globose, black in colour, and furnished with long spines, the latter arising from low mammillate projections, and forked at the ends, each branch of the fork usually again dividing at the tip into two very short branches, as shown in Fig. 11, *D*.

19. *C. subcostatum*, Nordst., Desm. Ital., Öfvers. af. K. Vet.-Akad. Förh., 1876, No. 6, p. 37, t. 12, fig. 13.

Long., 35–36 μ; lat., 28·8–30 μ; lat. isthm., 9–11 μ. Chloroplast with two pyrenoids.

Samples 361, 362 (rare).

C. subcostatum, forma *minor*, W. & G. S. West, " Alg. Central Africa," Journ. Bot., xxxiv, 1896, p. 379, t. 361, fig. 15; Brit. Desm., iii, 1908, p. 238, t. 87, figs. 6–9.

Long., 25–26 μ; lat., 18·6–21 μ; lat. isthm., 6 μ.

Chloroplast with one pyrenoid.

Samples 358, 359, 361, 362, 366, 367 (always very rare).

This form has been recorded from South-West Africa by G. S. West (1912).

20. *C. crenatum*, Ralfs, W. & G. S. West, *loc. cit.*, iv, 1912, p. 35, t. 98, figs. 9–12.

Long., 32 μ; lat., 22·7 μ; lat. isthm., 12 μ.

Samples 389, 390, 391 (very rare).

Not previously recorded from the Cape.

21. *C. speciosum*, Lund., var. *biforme*, Nordst., W. & G. S. West, *loc. cit.*, iii, p. 249, t. 89, figs. 4, 5.

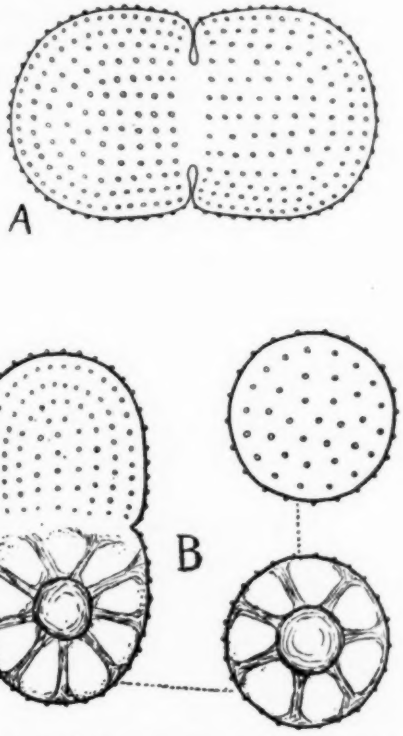


Fig. 12.—*A*, *B*. *A*, *Cosmarium conspersum*, var. *capense* var. nov., × 750; *B*, *Cos. Malmei* forma, × 1000.

Long., 57 μ; lat., 41 μ; lat. isthm., 27 μ.

Samples 365, 381 (very rare).

Not previously recorded from the Cape.

22. *C. conspersum*, Ralfs, var. *capense* var. nov. (Fig. 12, *A*).

Var. cellulis diametro 1¾ plo longioribus; semicellulis lateribus fere rectis leviterque divergentibus, aut leviter convexis, angulis superioribus valde rotundatis, apicibus rotundatis.

Long. cell., 70–76 μ ; lat., 41·5–44 μ ; lat. isthm., 18–22·5 μ.

Samples 389, 390, 391, 392 (very rare in each).

This variety usually had semicells with almost straight sides, usually slightly divergent, as in the typical form of *C. conspersum*. The apical part of the semicell, however, was strongly rounded, somewhat as in *C. conspersum*, var. *subrotundatum*, W. West ("Alg. W. Ireland," Journ. Linn. Soc. Bot., 1892, xxix, p. 152, t. 21, fig. 7). There were fifteen vertical series of granules visible in the front view. The vertical view was elliptic, as in the type.

23. *C. Malmei*, Borge, forma (Fig. 12, *B*).

Long. cell., 53·3 μ ; lat., 25·3 μ ; lat. isthm., 22·6 μ.

Sample 365 (very rare).

This appears to be a form of *C. Malmei*, Borge ("Algen Erst Regnellsch. Exped. II, Desmid.," Archiv f. Bot., 1903, Bd. 1, p. 85, t. 2, fig. 11), a species about which little is known. The cell-wall was colourless, with large conical obtuse granules in vertical series, about eleven or twelve vertical rows being visible in front view. The end view is circular. The original account by Borge does not include any description of the chloroplast. The present specimens showed a well-marked stellate chloroplast in each semicell, with a large central pyrenoid.

The front view very closely resembles that of *C.* (*Dysphinctium*) *Willei*, Turner ("Alg. E. India," Kongl. Sv. Vet.-Akad. Handl., Bd. 25, 1892, p. 42, t. 8, fig. 40), which, however, has an oval vertical view.

Genus Arthrodesmus Ehrenb.

1. *A. Incus* (Bréb.), Hass., var. *Ralfsii*, W. & G. S. West, forma *subhexagona*, W. & G. S. West, Brit. Desm., iv, 1912, p. 96, t. 114, fig. 6.

Long. cell., 16 μ ; lat. cum spin., 20 μ ; long. spin., 3·5 μ.

Sample 362 (very rare).

Not previously recorded from the Cape.

Genus Staurastrum Meyen.

1. *S. orbiculare*, Ralfs, var. *depressum*, Roy & Biss., W. & G. S. West, *loc. cit.*, iv, p. 158, t. 124, figs. 17–19.

Long. cell., 27–29 μ ; lat., 26–27 μ ; lat. isthm., 7·5–8 μ.

Diam. zygosp. cum spin., 38·4–40 μ.

,, ,, sine spin., 28·9–29 μ.

Long. spin., 4–6 μ.

Samples 357 (common, and with zygospores), 358.

The form of the cells was exactly as figured by W. & G. S. West, but the cell-wall was either smooth or obscurely punctate. The zygospores were

globose, with numerous acute spines. According to Messrs. West (*loc. cit.*), the zygospore of the var. *depressum* has not previously been recorded, but no figure of it is given here since it exactly resembled that of the var. *Ralfsii* (W. & G. S. West, *loc. cit.*, iv, p. 156, t. 124, fig. 16); while the var. *extensum*, according to Messrs. West, also has a similar form of zygospore.

Not previously recorded from the Cape.

2. *S. punctulatum*, Bréb., Ralfs' Brit. Desm., 1848, p. 133, t. 22, fig. 1; W. & G. S. West, *loc. cit.*, iv, p. 179, t. 127, figs. 8–11.

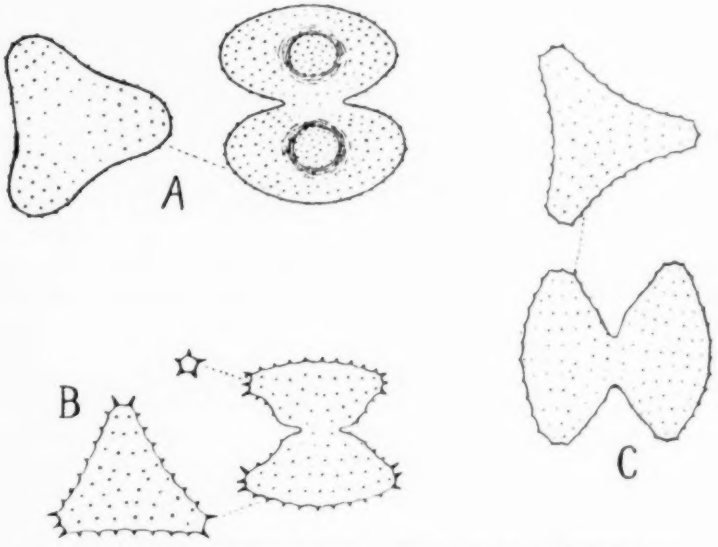


FIG. 13.—*A–C*. *A*, *Staurastrum alternans* forma; *B*, *St. Bohlinianum*, var. *capense* var. nov.; *C*, *St. hexacerum*, var. *reductum* var. nov. All × 1000.

Long. cell., 25·6–33 μ; lat., 22–27 μ; lat. isthm., 11·2–12 μ.

Samples 390, 391.

Already recorded from the Cape by Fritsch (1918).

3. *S. alternans*, Bréb., W. & G. S. West, *loc. cit.*, iv, p. 170, t. 126, figs. 8, 9.

Forma angulis non alternantibus (Fig. 13, *A*).

Samples 357, 358, 359, 361, 362 (always very rare).

In the shape of the semicells, and the granulations of the cell-wall, this agrees with *S. alternans*, but the angles of the two semicells were always superposed. According to W. & G. S. West (*loc. cit.*), the alternation of the semicells in this desmid is of no specific importance. Fritsch and Rich (1924) have recorded this form from Natal.

4. *S. Bohlinianum*, Schmidle ("Süsswasseralg. Pite Lappmark," etc., Bih. K. Sv. Vet.-Akad. Handl., **24**, iii, No. 8, 1898, p. 53, t. 3, fig. 3).

Var. CAPENSE var. nov. (Fig. 13, *B*).

Var. semicellulis a fronte visis late campanulatis, apicibus leviter convexis; membrana granulis in series circa 10 verticales digestis ornata; a vertice visis apicibus granulatis; processibus spinis brevibus 4 vel 5 praeditis.

Long. cell., 20–21·6 μ; lat. cum spin., 20–25 μ; lat. isthm., 5·3–7 μ.

Samples 357, 358, 361, 362.

This variety has less elliptic semicells than the type, and the granules are rather less numerous, although in similar vertical series; and the apex of the semicell is granulate.

5. *S. hexacerum*, Wittr., Gotl. Öl. sötv. Alg., 1872, p. 51; West and Carter, Brit. Desm., v, 1923, p. 138, t. 142, figs. 11–14.

Var. REDUCTUM var. nov. (Fig. 13, *C*).

Var. processibus brevibus, extremitatibus dentibus nullis instructis.

Long. cell., 28–32 μ; lat., 23–28 μ; lat. isthm., 7 μ.

Sample 366.

This variety is characterised by the short processes, and by the acute granules being no longer at the ends of the processes than elsewhere. The processes of the two semicells were always superposed.

6. *S. capense* sp. nov. (Fig. 14, *A*, *B*).

S. mediocre, diametro $1\frac{1}{4}$–$1\frac{1}{3}$ plo longioribus, profunde constrictum; semicellulis late oblongo-trapeziformibus, lateribus leviter convexis divergentibusque, angulis superioribus rotundatis et leviter productis, apicibus valde convexis; a vertice visae triangularibus, angulis rotundatis, lateribus leviter convexis; membrana granulis magnis rotundatis, circa angulos concentrice dispositis ornata.

Long. cell., 38–40 μ; lat., 29–32 μ; lat. isthm., 13 μ.

Sample 375 (very rare).

The shape of the cells in front view (Fig. 14, *A*) strongly resembles certain species of *Cosmarium*, especially *C. repandum*, Nordst. (W. & G. S. West, *loc. cit.*, iii, 1908, p. 53, t. 69, fig. 30), and also certain forms of *C. biretum*, Bréb. The latter species has a forma *triquetra*, Bréb. (W. & G. S. West, *loc. cit.*, iv, p. 28, t. 101, fig. 9), which, however, differs widely from the present species. It may also be compared with *S. kozlowskii*, Racib. ("Desmid. zebrane przez Dr. E. Ciastonia," Rospr. Wydz. matem.-przy. Akad. Umiej. Krakow, xxii, 1892, p. 387, t. 7, fig. 9).

7. *S. Manfeldtii*, Delp., var. AFRICANUM var. nov. (Fig. 14, *C*, *D*).

Var. minor quam forma typica, processibus brevioribus; semicellulis annulo granulorum circa basin praeditis.

Long. cell., 33–33·5 μ; lat. cum proc., 36–38 μ; lat. isthm., 8·6 μ.

Samples 357, 358, 361, 362 (very rare in each).

The front view of this variety (Fig. 14, *C*) much resembles the type, but has shorter processes, and there is a ring of granules round the somewhat swollen base of each semicell. It can be compared with the var. *annulatum*, W. & G. S. West (" Alg. N. Ireland," Trans. Roy. Irish Acad., xxxii, sec. B,

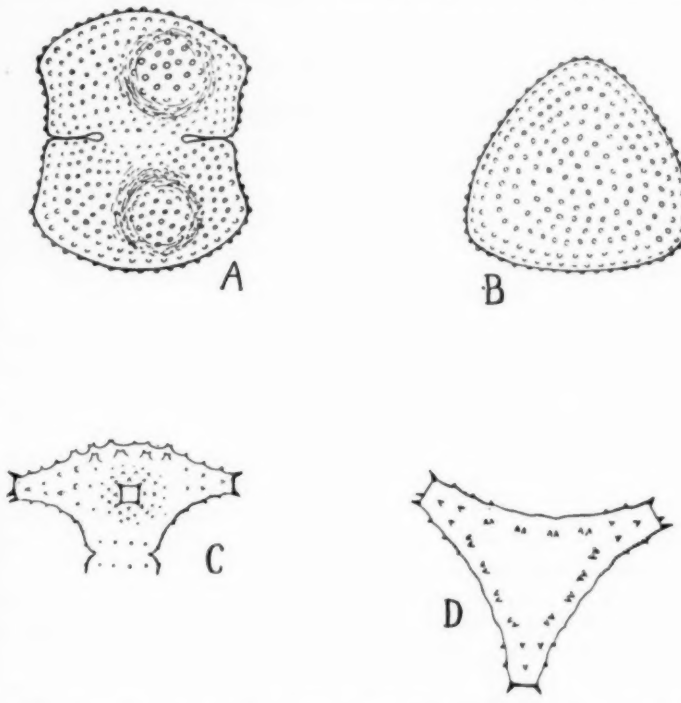


FIG. 14.—*A–D*. *A*, *B*, *Staurastrum capense* sp. n. *A*, front view ; *B*, end view. *C*, *D*, *St. Manfeldtii*, var. *africanum* var. nov. *C*, front view ; *D*, end view. All × 1000.

pt. 1, 1902, p. 56, t. 1, figs. 30, 31), which, however, has a double ring of granules round the base of the semicells, and also has longer processes. The present variety is also much smaller than either the type or the var. *annulatum*.

Genus SPONDYLOSIUM Bréb.

1. *S. pygmaeum* (Cooke), W. West, var. *capensis*, Fritsch, Ann. S. Afr Mus., ix, pt. 7, 1918, p. 562, fig. 33.

Long. cell., 12 μ ; lat., 8–10·6 μ ; lat. isthm., 5·5–6 μ.

Sample 389 (rare).

This agreed fairly well with the form described by Fritsch. The flattening of the apices of the cells was very marked, although in addition the middle of the apex was sometimes very slightly retuse. The cells were either united to form very short filaments, or were isolated.

Division HETEROKONTÆ.

Order HETEROCOCCALES.

Family OPHIOCYTIACEAE.

Genus Ophiocytium Näg.

1. *O. arbuscula* (A. Br.), Rabenh., Flor. Europ. Algar., iii, 1868, p. 68.
Sample 362 (very rare).
Already recorded from the Cape by Fritsch (1918).

Order HETEROTRICHALES.

Family TRIBONEMACEAE.

Genus Tribonema Derb. and Sol.

1. *T. bombycinum* (Ag.), Derb. and Sol., forma *genuinum* (Wille), Heering.
Samples 363, 365, 403.
—— forma *minor* (Wille), G. S. West.
Samples 363, 364, 368, 403.
Both forms already recorded from the Cape by Fritsch (1918), and the f. *minor* also by Fritsch and Stevens (1921).

Order HETEROSIPHONALES.

Family BOTRYDIACEAE.

Genus Botrydium Wallr.

1. *B. granulatum* (L.), Grev.
Sample 410.

The specimens had dried up in the tube, and were in such poor condition that very little of their structure could be made out. It is probable, however, that they belong to *B. granulatum*. Fritsch and Rich (1924) have recorded this species from Natal.

Group CYANOPHYCEAE.

Order COCCOGONEAE.

Family CHROOCOCCACEAE.

Genus Chroococcus Näg.

1. *C. minutus* (Kütz.), Näg., Gatt. einzell. Alg., 1849, p. 46.
Sample 359 (very rare).
Already recorded from South Africa by Wille (1903), Fritsch (1918), and Fritsch and Stevens (1921).
2. *C. minor* (Kütz.), Näg., *op. cit.*, p. 47.
Sample 353 (common), 404 (rare), 409 (rare).
Previously recorded from the Cape by Fritsch and Stevens (1921).

Genus Gloeocapsa Kütz.

1. *G. sanguinea* (Ag.), Kütz., Phyc. Gen., 1843, p. 174.
Sample 409 (common).
Already recorded from Natal by Fritsch and Rich.

Genus Aphanothece Näg.

1. *A. saxicola*, Näg., Gatt. einzell. Alg., 1849, p. 60, t. 1, fig. *H*, 2.
Crass. cell., 0·8–1·3 μ; long. cell., 2–4 μ.
Sample 380 (common).
Not previously recorded from the Cape.
2. *A. conferta*, Richter; Tilden, Myxophyceae of North Amer., i, 1910, p. 30.
Sample 352 (common).
Not previously recorded from the Cape.

Order HORMOGONEAE.

Family OSCILLATORIACEAE.

Genus Oscillatoria Vauch.

1. *O. tenuis*, Ag., Gomont, Ann. Sci. Nat., sér. 7, xvi, 1892, p. 220, t. 7, figs. 2, 3.
Sample 354 (rare).
Already recorded from various parts of South Africa.
2. *O. amphibia*, Ag., Gomont, *loc. cit.*, p. 221, t. 7, figs. 4, 5.
Sample 354 (rare).
Also recorded from the Cape by Fritsch (1918).

3. *O. formosa*, Bory ; Gomont, *loc. cit.*, p. 230, t. 7, fig. 16.
Sample 379 (common).

Recorded from the Cape by Fritsch (1918), Fritsch and Stevens (1921), and Fritsch and Rich (1924).

4. *O. defleza*, W. & G. S. West, forma (?).
Crass. trich., 1·2–1·3 μ ; long. cell., 2–3 μ (Fig. 15, *A–C*).
Samples 406, 407.

This has tentatively been considered as a form of *O. deflexa*, W. & G. S. West (Rep. Brit. Antarct. Exped., 1907–9, i, pt. 7 ; Freshw. Alg., 1911, p. 295, t. 25, figs. 95–97), although differing somewhat from this species. The trichomes, which lacked a sheath, were straight or slightly flexuose, but never spirally twisted as mentioned by Messrs. West in the case of *O. deflexa*. The cross-walls were indistinct, and the trichomes were not

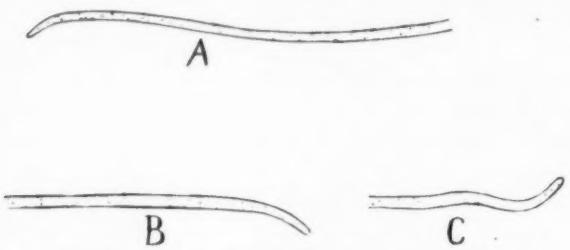


Fig. 15.—*A–C*, *Oscillatoria deflexa* forma (?). × 1500.

constricted. Small granules were present, and frequently there was one (sometimes two) each side of every transverse wall. The apex of the trichome was slightly tapering, and the trichome itself was slightly and frequently rather suddenly curved just behind the apex (Fig. 15, *A*, *B*). This curvature near the apex seems to be a characteristic feature of the present form, although it was often less marked than figured by W. & G. S. West in the case of *O. deflexa*. The latter also appears to have a rather more tapering apex. In some respects the present specimens can be compared with *O. subtilissima*, Kütz., and *O. angustissima*, W. & G. S. West.

Genus Phormidium Kütz.

1. *P. autumnale* (Ag.), Gom., *loc. cit.*, 1892, p. 187, t. 5, figs. 23, 24.
Samples 351, 354, 355, 372.
Already recorded from the Cape.
2. *P. corium* (Ag.), Gom., *loc. cit.*, p. 172, t. 5, figs. 1–2.
Samples 351, 355, 356, 377.
Not previously recorded from the Cape.

3. *P. retzii* (Ag.), Gom., *loc. cit.*, p. 197, t. 5, figs. 6–9.
Sample 350.
Recorded from Natal by Fritsch and Rich.
4. *P. calidum*, Gom., *loc. cit.*, p. 182, t. 5, fig. 16.
Samples 406, 407.
Not previously recorded from the Cape
5. *P. tenue* (Menegh.), Gom., *loc. cit.*, p. 189, t. 4, figs. 23–25.
Samples 350, 352, 355, 366, 378, 404.
Already recorded from various parts of South Africa.

Genus Microcoleus Desmaz.

1. *M. chthonoplastes*, Thuret, "Essai Class. Nostoch.," Ann. Sci. Nat. Bot., sér. 6, i, 1875, p. 378.
Crass. fil., 28·8–42 μ; crass. trich., 5 μ.
Sample 367 (very rare).
Already recorded from the Cape by Fritsch and Stevens (1921).

Family SCYTONEMACEAE.

Genus Microchaete Thur.

1. *M. diplosiphon*, Gomont, var. tenuis var. nov.
Var. minor, trichomatibus tenuioribus (Fig. 16, *E–G*).
Crass. fil., 7–8 (–10) μ; crass. trich., 2·7–4 μ.
,, cell. bas., ad 6·6 μ.
,, heterocyst. bas., 5·5–8 μ.
Long. heterocyst. bas., 5·5–8·5 μ.
Crass. heterocyst. intercal., 3·3–4 μ.
Long. heterocyst. intercal., 13–23 μ.
Crass. spor., 4–6 μ.
Long. spor., 9–16 μ.
Samples 389 (common), 390, 391 (very rare).

Except for the somewhat narrower trichomes this agreed with the typical form of *M. diplosiphon*. The cells adjoining the basal heterocysts are much shorter than those of the rest of the filament, and also generally wider (up to 6·6 μ), and more swollen or barrel-shaped (Fig. 16, *E*). The basal heterocysts are globose or subglobose, while the intercalary ones are much elongated (Fig. 16, *F*). The sheath of the filament was always double, the inner one being much firmer than the outer, the latter often becoming mucous and diffluent. At the ends of the filament the firmer inner sheath often extends beyond the outer sheath. Both sheaths were colourless, or very rarely had a slight yellowish tint.

Spores (Fig. 16, *G*) were frequent and cylindrical in shape. They occurred

in series of 2–11, and were usually adjacent to a heterocyst (either basal or intercalary); rarely were they remote from a heterocyst. The spore-wall was thick, smooth, and light yellow-brown in colour.

2. M. CAPENSIS sp. nov. (Fig. 16, *A–D*).

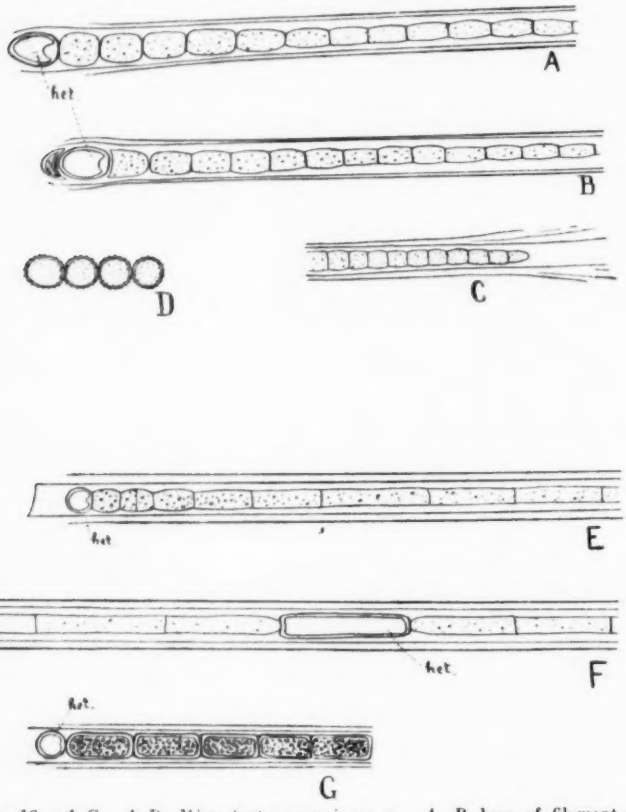


FIG. 16.—*A–G*. *A–D*, *Microchaete capensis* sp. n. *A*, *B*, base of filament; *C*, apex; *D*, row of spores. *E–G*, *Microchaete diplosiphon*, var. *tenue* var. nov. *E*, basal part of a filament; *F*, part of filament showing an intercalary heterocyst; *G*, seriate spores next to a basal heterocyst. All × 750.

M. filis dense intricatis; vaginis achrois, saepe duplicibus, ad apicem saepe lamellosis; trichomatibus inter cellulas constrictis, ad apicem leviter attenuatis; cellulis diametro 1–2 (–3) plo longioribus, cellulis basalibus crassioribus, saepe valde turgidis, cellula apicali obtuse rotundata; heterocystibus basalibus subglobosis, subellipsoideis vel subtriangularibus,

solitariis vel 2–3 seriatis; heterocystibus intercalaribus nullis. Sporae juxta heterocystes, 3–10 seriatae, globosae, subglobosae vel subellipsoideae; episporio achroo, spinis obtusis, brevissimis praedito.

Crass. fil. (in medio), 6·6–8 μ.
,, trich. (in medio), 3–4 μ.
,, trich. (ad bas.), 4–7 μ.
,, heterocyst., 5–7 μ; long., 7–10 μ.
,, spor., 5·3–6 μ; long., 5·3–7·5 μ.

Sample 404 (common).

This is stated to have formed a " dark green felt " on the sides of a glass tank in the laboratory. The base of the filaments were generally swollen, with a bulbous appearance due to the enlarged basal cells and heterocysts (Fig. 16, *A*, *B*).

These basal cells appear to be in process of active division, and are subquadrate or rectangular in shape, but rapidly elongate as they are traced upwards. The cells are more or less barrel-shaped owing to the constriction of the trichome at the cross-walls. The trichomes gradually taper from base to apex, the tapering being slightly more pronounced towards the apex. The apical cell is bluntly rounded.

There is usually only one basal heterocyst, but sometimes a series of two or three occurs, and very frequently there could be seen shrivelled remains of what appeared to be heterocysts at the extreme base of the trichome (Fig. 16, *B*). The sheath was often apparently simple, but at other times appeared double, while at the apex of the filament it generally broadened out somewhat and became more or less lamellose (Fig. 16, *C*). The external surface of the sheath was often irregular. Occasionally the trichomes were interrupted at intervals in the sheath. No false branching was observed.

Spores were not very abundant. They occurred in series adjacent to the heterocyst, and had a wall of only moderate thickness, which was colourless and rather densely covered with very short blunt spines (Fig. 16, *D*). The spores are developed from the swollen basal cells of the trichome, which swell up and become more or less rounded in the process.

Family STIGONEMACEAE.

Genus Stigonema Ag.

1. *S. hormoides*, Born. et Flah., " Revis. d. Nostoc. Heterocyst.," Ann. Sci. Nat. Bot., sér. 7, v, 1887, p. 68.

Sample 409 (rare).

Already recorded from the Cape by Fritsch (1918), and from Natal by Fritsch and Rich (1924).

Family NOSTOCACEAE.

Genus Anabaena Bory.

Isolated vegetative (and therefore indeterminate) filaments of this genus were occasionally seen (in samples 367, 368, 406, 407).

Genus Nostoc Vauch.

1. *N. commune*, Vauch., Bornet et Flahault, *loc. cit.*, 1888, p. 203.
Crass. cell., 4–4·3 μ; long. cell., 5–6 (–7) μ; diam. heterocyst., 6–7 μ.
Sample 360.

Very common on the flats near the town, and often covering large areas of (usually) clayey ground. In the summer the thalli dry up completely and form blackish membranous expansions which crumble between the fingers, but after rain they become gelatinous.

The filaments of the outermost layers of the " peridium " of the thallus are densely contorted and have yellowish-brown distinct sheaths; but the sheaths of the inner filaments are hyaline and more or less diffluent. The cells are oval or subglobose; the heterocysts subglobose, occurring singly or in pairs (rarely three together). No spores were seen.

Not previously recorded from the Cape.

Genus Cylindrospermum Kütz.

1. *C. majus*, Kütz., Phyc. Gen., 1843, p. 212.
Sample 402 (very rare).
Not previously recorded from the Cape.

Class BACILLARIEAE (DIATOMALES).

Order CENTRICAE.

Family MELOSIRACEAE.

Genus Melosira Ag.

1. *M. granulata*, Ehrenb.
Sample 349 (very rare).

Family COSCINODISCACEAE.

Genus Cyclotella Kütz.

1. *C. Meneghiniana*, Kütz.
Sample 390 (very rare).

Genus Coscinodiscus Ehrenb.

1. *C. lacustris*, Grun.
Samples 349, 366 (very rare).

Order PENNATAE.

Family FRAGILARIACEAE.

Genus Tabellaria Ehrenb.

1. *T. flocculosa*, Kütz., var. *ventricosa*, Grun.
Sample 390 (very rare).

Genus Fragilaria (Ralfs), Grun.

1. *F. mutabilis*, Grun.
Long., 13–14 μ; lat., 6–6·7 μ; 10–11 striae in 10 μ.
Samples 351, 356, 359 (very rare).

Genus Synedra Ehrenb.

1. *S. pulchella*, Kütz.
Long., 48–53 μ; lat., 2·1–2·6 μ; 16–17 striae in 10 μ.
Pseudonodule rather indistinct.
Samples 367, 368 (very rare).
2. *S. Vaucheriae*, Kütz.
Long., 20–36 μ; lat., 2–3 μ; 22–24 striae in 10 μ.
Lateral pseudonodule distinct.
Sample 359 (rather frequent).
3. *S. Ulna*, Ehrenb., var. *aequalis* (Kütz.), Brun.
Sample 351.
—— var. *danica* (Kütz.), Grun.
Samples 390, 391, 392.
—— var. *vitrea*, Kütz.
Samples 367, 368, 403.
Some of the forms of this variety were distorted, and approached *S. vitrea* var. *distorta*, Meister (Kieselalg. d. Schweiz., 1912, p. 77, t. 8, fig. 7).

Family EUNOTIACEAE.

Genus Eunotia Ehrenb.

1. *E.* (*Himantidium*) *pectinalis*, Kütz.
Samples 357, 359, 365, 366, 368, 369.
—— var. *minor*, Grun.

Samples 365, 381, 394.

—— var. *media*, O. Müll.

Samples 357, 356, 365, 366, 368, 369.

—— var. *impressa*, O. Müll.

Samples 356, 368.

2. *E. bicapitata*, Grun.

Long., 204 μ; lat., 7·5 μ; lat. apic., 8 μ; 12 striae in 10 μ.

Sample 359 (very rare).

Family ACHNANTHACEAE.

Genus Achnanthes Bory.

1. *A.* (*Microneis*) *minutissima*, Kütz.

Long., 12–17·3 μ; lat., 2·7–3 μ.

Samples 390, 391, 392.

2. *A.* (*Achnanthidium*) *coarctata*, Grun.

Samples 367, 403 (very rare).

3. *A.* (*Achnanthidium*) *subsessilis*, Kütz. [=*A. brevipes*, var. *intermedia* (Kütz.), Cl.].

Samples 349, 358, 359, 361.

Family NAVICULACEAE.

Genus Navicula Bory.

1. *N.* (*Caloneis*) *silicula*, Ehr., var. *gibberula*, Kütz.

Samples 367, 381, 407.

2. *N.* (*Neidium*) *amphirhynchus*, Ehr., var. *minus* (Cl.), Meister.

Long., 33·5–34·5 μ; lat., 6–7 μ.

Samples 369, 375.

3. *N.* (*Neidium*) *affinis*, Ehr.

Sample 375 (very rare).

4. *N. cuspidata*, Kütz., var. *angusta*, Dippel.

Long., 65–67 μ; lat., 15–16 μ; 17–18 striae in 10 μ.

Samples 358, 361.

—— var. *ambigua* (Ehr.), Cl., forma *craticula*, V. H. (Treat. Diat. Eng. Ed., p. 214, t. 4, fig. 193).

Valve with broad transverse rib-like thickenings.

Sample 367 (very rare).

5. *N.* (*Frustulina*) *rhomboides*, Ehr.

Long., 104–109 μ; lat., 21–24 μ; 24 striae (trans. and long.) in 10 μ.

Samples 359, 369, 370.

—— var. *saxonica*, Rabenh.

Long., 53 μ ; lat., 13 μ.

Sample 356.

6. *N.* (*Frustulina*) *vulgaris*, Thwaites.

Samples 351, 356, 358, 359, 362, 369, 394.

7. *N. mutica*, Kütz., var. *Cohnii*, Grun., Van Heurck, Syn., t. 10, fig. 17.

Samples 407, 390 (very rare).

—— var. *undulata*, Hilse.

Samples 392, 407 (very rare).

8. *N.* (*Anomoioneis*) *exilis*, Kütz.

Sample 357.

9. *N.* (*Anomoioneis*) *serians*, Bréb., var. *brachysira* (Bréb.), V. H. (=*N. brachysira*, Bréb.).

Long., 20–22 μ ; lat., 7 μ.

Sample 369.

10. *N. cocconeiformis*, Greg.

Sample 402 (very rare).

11. *N. cincta*, Ehrenb.

Samples 372, 379, 394, 402.

12. *N. cryptocephala*, Kütz.

Samples 349, 369, 379.

—— var. *exilis*, Kütz.

Sample 377.

13. *N. viridula*, Kütz.

Sample 361.

14. *N. Gastrum*, Ehr., var. *exigua*, Grun.

Long., 18–20 μ ; lat., 9 μ.

Samples 375, 381, 407.

15. *N. anglica*, Ralfs, var. *minuta*, Cl.

Long., 17·5–23 μ ; lat., 8 μ.

Sample 389 (very rare).

16. *N. dicephala*, W. Smith.

Samples 352, 356 (very rare).

17. *N. lanceolata*, Kütz.

Sample 351 (very rare).

18. *N.* (*Pinn.*) *interrupta*, W. Sm., forma *biceps* (Greg.), Cl. (=*Pinnularia biceps*, Greg.).

Sample 369 (very rare).

—— forma *subbicapitata*, Fritsch (Ann. S. Afr. Mus., ix, 1918, pt. 7, p. 592, fig. 40*d*).

Samples 357, 375, 377.

—— forma *subcapitata* (Greg.), Fritsch (*loc. cit.*, p. 592, fig. 40*c*) (=*Pinnularia subcapitata*, Greg.).

Samples 369, 389, 391.

—— forma *Braunii* (Grun.), Fritsch (*loc. cit.*, p. 592, fig. 40*a*, *b*) (=*Pinn. Braunii*, Grun.).

Samples 351, 357, 358, 361, 362, 363, 364, 368, 377.

19. *N.* (*Pinn.*) *mesolepta*, Ehr.

Sample 358 (very rare).

20. *N.* (*Pinn.*) *microstauron*, Ehr.

Long., 36 μ; lat., 8 μ; 11–12 striae in 10 μ.

Sample 351 (very rare).

21. *N.* (*Pinn.*) *Brébissonii*, Kütz.

Samples 358, 375, 389.

—— var. *subproducta*, V. H.

Samples 363, 364, 368.

—— var. *diminuta*, V. H.

Long., 20–26 μ; lat., 4·2–4·7 μ; 9–10 costae in 10 μ.

Samples 358, 375, 381, 407.

22. *N.* (*Pinn.*) *legumen*, Ehr.

Long., 76–80 μ; lat., 10·6–12 μ; 11 costae in 10 μ.

Samples 377, 389.

23. *N.* (*Pinn.*) *lata* (Bréb.), Rabenh., var. *latestriata* (Greg.), Cl.

Long., 48–64 μ; lat., 10·5–13 μ; 4$\frac{1}{2}$ costae in 10 μ.

Sample 381 (very rare).

24. *N.* (*Pinn.*) *borealis*, Ehr.

Samples 358, 369, 381, 407.

—— forma *rectangularis*, Carlson (Fritsch, *loc. cit.*, 1918, p. 593, fig. 40*f*).

Samples 351, 358 (very rare).

25. *N.* (*Pinn.*) *esox*, Ehr.

Long., 101–133 μ; lat., 14·5–18 μ; 8–8$\frac{1}{2}$ striae in 10 μ.

Samples 362, 368.

26. *N.* (*Pinn.*) *viridis*, Ehr.

Samples 352, 358, 361, 362, 363, 364, 394.

Genus Stauroneis Ehr.

1. *S. Phoenicenteron*, Ehr., var. *amphilepta*, Ehr.

Long., 70–84 μ; lat., 16 μ.

Samples 358, 362, 369.

2. *S. anceps*, Ehr.

Samples 357, 358, 375.

—— var. *elongata*, Cl.

Samples 358, 381.

3. *S.* (*Pleurostauron*) *acuta*, W. Sm.

Sample 358.

A small form of this species (long., 45 μ; lat., 9·6 μ; 18 striae in 10 μ), with the characteristic rhombic-lanceolate shape, occurred in sample 381.

4. *S.* (*Pleurostauron*) *parvulum* (Grun.), var. *producta*, Grun.

Long., 33–41 μ; lat., 8·5 μ; 18–20 striae in 10 μ.

Sample 369 (very rare).

Family GOMPHONEMACEAE.

Genus Gomphonema Ag.

1. *G. constrictum*, Ehr., var. *capitatum*, Cl.

Samples 351, 389, 390, 391, 392.

2. *G. angustatum*, Grun.

Samples 366, 394.

3. *G. gracile*, Ehr.

Samples 351, 359, 368.

—— var. *naviculoides*, W. Sm.

Samples 359, 378, 389, 390, 391, 392.

4. *G. intricatum*, Kütz.

Samples 357, 358, 361.

5. *G. acuminatum*, Grun., var. *coronatum*, Grun.

Sample 390 (very rare).

6. *G. subclavatum*, Grun.

Samples 358, 361, 362, 363.

7. *G. parvulum*, Kütz.

Samples 357, 358, 359, 366, 378, 389, 394.

—— var. *subellipticum*, Cl.

Long., 13–16 μ; lat., 5·3–6·5 μ.

Samples 366, 394.

Family COCCONEMACEAE.

Genus Cymbella Ag.

1. *C.* (*Encyonema*) *ventricosa*, Kütz., var. *ovata*, Cl.

Samples 358, 367, 402.

—— var. *lunula*, Meister.

Samples 389, 391.

2. *C.* (*Encyonema*) *gracilis*, Rabenh.

Sample 356 (very rare).

Genus Amphora Ehr.

1. *A. ovalis*, Kütz., forma *typica*, Cl.

Sample 349.

—— var. *gracilis*, Ehr.
Samples 358, 363.
2. *A. Normani*, Rabenh.
Sample 402 (very rare).

Genus Rhopalodia O. Müll.

1. *R. gibberula* (Kütz.), O. Müll., var. *minuta* (Hantzsch), Rabenh.
Long., 15–24 μ.
Sample 349 (very rare).
—— var. *producta*, Grun.
Ends of the valve rostrate and curved towards the ventral side.
Samples 357, 358, 362.

Family NITZSCHIACEAE.

Genus Tryblionella (W. Sm.), Grun.

1. *T. Hantzschiana*, Grun., var. *levidensis*, W. Sm.
Sample 349 (very rare).
2. *T. debilis*, Arnott and Rylands (Van Heurck, Treat. Diat. Eng. Ed., p. 385, t. 15, fig. 497).
Long., 19–20 μ; lat., 8–9 μ.
Striae very faint and interrupted down the middle of the valve.
Sample 402 (very rare).

Genus Nitzschia Hass.

1. *N. hungarica*, Grun., var. *linearis*, Grun.
Long., 82 μ; lat., 7·3 μ; 9½ keel puncta and 17–18 striae in 10 μ. Valve linear, not constricted.
Sample 402 (very rare).
2. *N. thermalis*, Grun., var. *intermedia*, Grun.
Long., 50–55 μ; lat., 7·3–8 μ; 9–10 keel puncta in 10 μ; striae very fine.
Samples 358, 379 (very rare).
3. *N. linearis* (Ag.), W. Sm.
Sample 367.
4. *N. amphibia*, Grun.
Long., 31 μ; lat., 4 μ; 16 coarsely punctate striae in 10 μ.
Sample 402.
5. *N. communis*, Rabenh.
Sample 352.
6. *N. palea*, Kütz.
Samples 350, 359, 363, 366, 377, 379, 389, 394, 407.

7. *N.* (*Nitzschiella*) *longissima* (Bréb.), Ralfs, var. *reversa* (W. Sm.), V. H.
The two rostra curved in opposite directions.
Sample 387 (very rare).

Genus Hantzschia Grun.

1. *H. amphioxys* (Kütz.), Grun., var. *genuina*, Meister.
Sample 363.
—— var. *intermedia*, Grun.
Sample 363.
—— var. *pusilla*, Dippel.
Samples 351, 358, 368, 372, 381, 394, 402.
—— var. *elongata*, Hantzsch.
Sample 368.
—— var. *capitata*, Pant. (Meister, Kieselalg. d. Schweiz, 1912, p. 203, t. 36, fig. 3).
Long., 60 μ; lat., 5·3 μ; keel puncta, 8–9 in 10 μ.
Sample 358.

Family SURIRELLACEAE.

Genus Surirella Turp.

1. *S. angusta*, Kütz., var. *pinnata* (W. Sm.), Meister (=*S. pinnata*, W. Sm.), *loc. cit.*, p. 223, t. 41, fig. 8.
Long., 27–33 μ; lat., 7–8 μ; 6–7 costae in 10 μ.
Samples 363, 364, 366, 367, 368.
2. *S. robusta*, Ehr., var. *splendida*, Kütz.
Sample 390 (very rare).

NOTE ON A BURIAL-STONE.

By S. H. Haughton, B.A., D.Sc., F.G.S.

(With Plate V.)

The plate issued in this part (Plate V) is a reproduction of a "burial-stone" which is now in the South African Museum, Cape Town. It was prepared under the direction of the late Dr. L. Péringuey as part of the illustrations of a contemplated continuation to his published monograph on "The Stone Ages of South Africa" (Ann. S. Afr. Mus., vol. viii).

I have found among Dr. Péringuey's MSS. a large amount of material consisting mostly of notes and accounts of the various rock-shelters which were excavated under his direction; but the MSS. is not complete enough to warrant its publication. It has been, therefore, thought advisable to issue this plate on account of its interest for anthropologists, and to accompany it with very brief notes relative to its mode of occurrence.

The stone figured in the plate is from the Coldstream shelter in the Division of Humansdorp, and was discovered by Mr. J. Drury of the South African Museum during his excavations there in February 1911. The stone (a semi-oval, river-worn boulder) was found lying on the shoulder of a skeleton, with the feet of the painted figures next to the jaw of the skeleton, the painted side upwards. The skeleton itself was lying on its left side, with the head close to the back of the cave and facing north or north-eastwards. There was also a flat stone lying on the hip of the skeleton; but this bore no trace of painting, and was of a rougher nature, with its edges but slightly trimmed.

In his notes, Dr. Péringuey makes the following remarks on this specimen. "Briefly explained, there is" (on the stone figured in Plate V) "on the right a man—to a certain extent drawn conventionally—possibly in the act of throwing a dart. The middle person carries a quiver full of arrows slung from the shoulder; in his left hand he holds his club, and in the other what seems to be at first sight a feather, but what is in reality a jackal's tail, as is proved by the black barring which is not apparent in the reproduction, but is quite obvious in the original. Of the third man or woman nothing need be said beyond the fact that he or she wears a cap.

"In 1620, Commodore Beaulieu, a French commander on his way to

the East Indies, landed in Table Bay. He took a day's journey round the mountain, and met with natives. He commented on the miserable manner in which they lived and on their small stature; and continued: 'Those who seem to have some command over the rest have commonly a stick in their hands with a fox's tail at the end of it.' This part of Beaulieu's narrative is of interest in connection with this picture."

Other burial-stones, showing a different type of technique in monochrome, and apparently depicting people strongly marked by steatopyga, have been found in several rock-shelters along the southern littoral; but this is, so far, the only stone discovered on which the artist has used the three common colours of the so-called "Bush" paintings.

Printed in Germany.

NOTES ON THE HABITS AND LIFE-HISTORIES OF CERTAIN LITTLE-KNOWN ANURA, WITH DESCRIPTIONS OF THE TADPOLES.

By J. H. Power.

(With Plates VI–IX and five Text-figures.)

An excursion, under the auspices of the M'Gregor Museum, Kimberley, was made to Lobatsi by the author and Mr. S. Tapscott early in December 1924. The primary object of the visit was the collecting of plants, principally succulents, for the Karroo Garden in connection with the Museum, but opportunity was taken to study the Batrachia of the neighbourhood. The following is an account of the observations made.

CASSINA.

This genus contains only two species, *Cassina senegalensis* Dumeril and Bibron, and *Cassina obscura* Boulenger. The latter gives a third species, *Cassina wealii*,* but, as Hewitt points out,† it is probably a synonym of *Cassina senegalensis*. Recently Noble ‡ compared a specimen of the so-called *Cassina wealii* from the Cape with a large series of *Cassina senegalensis* from Niangara (3° 40′ N., 27° 50′ E.), and could find no difference between them. There is apparently so much variation within the species as to include all the specific characters given for *Cassina wealii*.

Cassina senegalensis has a wide distribution. The type came from the lakes in the vicinity of Galam, Senegal, and it seems to occupy all the country from the Sahara to the Cape with the probable exception of the intervening forests.

Habits.—It is essentially terrestrial, and probably frequents water for breeding purposes only.

Ordinarily it is a running frog, but when hard pressed it hops. Nocturnal,

* Cat. Batra. Sal. Brit. Mus., 1882, p. 131, pl. x, fig. 7; also Ann. S.A. Mus., v, 1910, pt. 9, p. 532.

† Rec. Alb. Mus., ii, 1912, p. 224.

‡ Bull. Amer. Mus. Nat. Hist., xlix, 1924, p. 233.

spending the day in holes and crevices under stones, coming forth at night to eat insects, principally termites and ants.

At Kimberley the breeding season begins after the first rains, when the males may be heard calling, usually here in October. They are not particular as to the breeding site ; any muddy pool of fairly large size may be selected. The writer has found them breeding in a muddy pool near Kimberley, and in clear water at Lobatsi. The water may be open or have reeds growing in it.

The males sit on the edge or some distance away from the water, making a sound resembling the bursting of a large bubble or the withdrawing of a cork from a bottle. The sound is so characteristic that when once heard there is no mistaking it. The sucker-like fold beneath the head is the vocal sac. This is white, and is blown forward, being expanded to about twice its normal size. Then a curious thing happens. At either side of the fold a thin chocolate-coloured membrane becomes suddenly distended, as shown in Pl. VI, fig. 2, and as suddenly collapses, producing the sound described above. The call is so loud that it may be heard more than a mile away, and is repeated at intervals of about a minute.

The species was fairly plentiful at the pool where these observations were made. As soon as an individual lifted his voice others followed suit, the similarity to a series of corks being drawn being ludicrous. In the female the vocal sac is absent.

At first sight it would appear as if the embrace were in the lumbar region, for the male lies far back on the female, but as a matter of fact the female is grasped by the whole forearm, the elbows being in the lumbar region while the hands reach almost under the arms. The male allows the pair to be taken in the hand without relaxing his hold.

Metamorphosis.—The eggs (Pl. VI, fig. 3) are small and hard, measuring 1·5 mm. in diameter ; dark brown above with the lower pole yellowish white ; in single mucilaginous capsules measuring 2 mm. in diameter, in newly laid eggs there is scarcely any difference between the capsule and the vitelline egg. They are attached singly or in pairs, but sometimes three or four may be found attached in a row to pieces of decaying wood, leaves, grass, etc., on the bottom of the pool. An area of about two square yards was marked off in the pool on the night of December 15th ; on the following morning twenty eggs were collected there. A pair taken in embrace were put into water in a small covered tin, 105 mm. in diameter and 113 mm. deep, and left there during the night ; in the morning fourteen eggs were found attached to the bottom. Of these only five proved fertile. From this it would seem that the number of eggs laid by an individual female is from 14 to 20, although, considering the fairly long period of metamorphosis (90 days), this number is unusually few.

December 17th.—The egg capsule measured 2·5 mm. in diameter and the embryo had begun to form ; external gills were visible in the shape of tiny buds.

December 20th.—The embryo, still within the egg capsule (Pl. VI, fig. 4), measured 5 mm. in diameter ; external gills were now branched.

December 21st.—Total length 6 mm., tail 3·5 mm.

The tiny tadpoles began to leave the capsule. There was a fairly well-developed tail fin, and the eyes, in the form of tiny brown spots, appeared. The upper portion of the body was a yellowish brown, the yolk sac whitish, the branched gills brown.

December 22nd.—Total length 6·5 mm., tail 4·5 mm.

The eyes were now black spots ; external gills began to disappear ; the characteristic median and lateral stripes of the young tadpoles began to appear.

December 23rd.—Total length 7 mm., tail 4·5 mm.

Anal opening now visible.

December 27th.—Total length 9·5 mm., tail 6 mm.

The mouth parts were now seen ; the intestines showed food. The spiraculum was apparent.

January 12th.—Total length 23 mm., tail 15 mm.

The legs began to appear in the shape of tiny white buds at the root of the tail.

February 2nd.—Total length 37·5 mm., tail 25 mm.

The characteristic median and lateral stripes had now disappeared ; the tadpole being a uniform olive green above with tiny spots.

March 2nd.—Total length 74 mm., tail 38 mm.

This was the maximum length reached (see Pl. VII, figs. 1 and 2). Not being nearly so active as before, they were inclined to rest longer on the bottom.

March 6th.—Total length 54 mm., tail 34 mm.

The arms appeared, first the left through the spiracular opening. The characteristic markings of the adult were very apparent.

March 10th.—Total length 50 mm., tail 33 mm.

The tiny, now air-breathing, frogs began to show a desire to be near the surface and have their heads above the water. The tail was not completely absorbed until March 16th, ten days after the appearance of the arms ; an unusually long period. The tiny frog, having the colour and characteristic markings of the adult, measured 18 mm. It now left the water completely, and hid in damp corners under stones. In the case of another specimen removed from the water on March 10th, the tail shrank from 32 mm. to 15 mm. in six hours.

Thus the metamorphosis in a small aquarium took 90 days to complete.

Tadpole.—The following description of the tadpole was taken from specimens of maximum size (Pl. VII, figs. 1, 2, 3). Length of body one and three-quarter times its width ; nearly seven-elevenths of the length of the tail. Eyes at the sides, equally visible from above and below ; the distance between them three times the distance between the nostrils ; equal to the width of the mouth.

Spiraculum large, directed backwards and slightly upwards, low down on the left side just behind the eye and equidistant from either extremity of the body. Anal opening on the right side just beneath the junction of the leg and body, very much smaller than the spiraculum.

Tail slightly more than twice as long as deep, tapering to an acute point. Upper crest appreciably convex, lower one but very feebly so ; the former extending more than half-way up the back to the level of the middle of the eyes ; the depth of the muscular part at its base two and a half times the total depth.

Mouth elliptical (Pl. VI, fig. 1), lip bordered with papillae which form two or more rows on the sides ; broadly interrupted in the middle of the upper lip ; with a well-marked chink on either side of the lower lip. Beak black, and having a toothed saw-like edge, the lower portion more than twice the depth of the upper : the series of labial teeth $\frac{1}{2}$ occupying the whole width of the lips ; the second lower interrupted in the middle ; all the series formed of one row of teeth. Lines of crypts, sometimes very apparent in the more advanced stages, extend from the nostrils to the eye on either side (fig. 1). Colour : olive green above ; whitish beneath ; caudal crests sometimes transparent ; at others marbled with dark brown.

The tadpoles are very voracious, eating almost anything that is given to them. I have noticed them bite through the stems of growing water-weeds the moment they were put into a tank containing them. It is also a most interesting and important fact that they devour mosquito eggs, the tanks containing Cassina tadpoles being remarkably free from the larvae, while in those containing the tadpoles of other species the larvae was plentiful. As many as twenty rafts of mosquito eggs were counted on the surface one morning, and while the writer watched he saw them being eaten up. Thus in both adult and larval stages this frog is a great ally of man, and should be encouraged to increase and multiply.

PHRYNOMANTIS.

There are five known species of this genus in Africa, three of which occur south of the Zambesi, but they are so secretive that very little is known of their habits.

Phrynomantis bifasciata has a very wide range, occupying practically

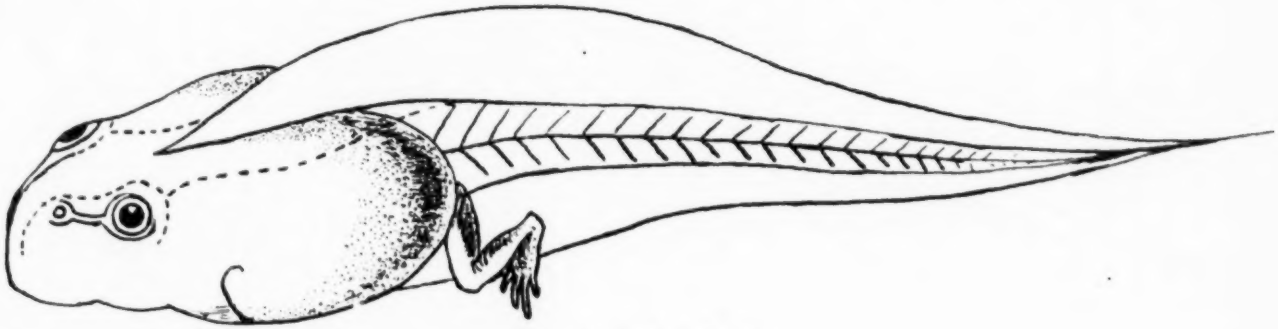


FIG. 1.—Showing lines of crypts.

all the country from 27° S. to Angola and Kenya Colony. Specimens occasionally turn up at Kimberley in the neighbourhood of the mines, but the species is not known to occur in the surrounding country. A large quantity of the mine timber and firewood comes from the Bechuanaland Protectorate, and probably it is introduced in this way. Possibly in time it may become permanently established at Kimberley. It is fairly common at Vryburg ; the Kimberley Museum possesses seventeen specimens taken in the mining area, principally at Bultfontein and Wesselton.

Habits.—Its food consists almost entirely of ants and termites : is nocturnal, spending the day in holes in old wood or in burrows in the ground. Even at night in the breeding season it does not call out in the open as do all the other frogs known to me. Instead, it sits in crevices or under stones near the water's edge, giving vent at intervals to a quiet, shrill whistle, somewhat resembling cur-r-r-r-uu, which is repeated at intervals of a minute or so. One specimen carried home in a box continued his call at intervals all the way. The vocal sac when inflated is shiny black, and smaller proportionately than that of any frog I know. Unfortunately no pairs were seen, but a mass of newly hatched eggs, numbering approximately 400, was found resting on algae in mid-stream on December 19th. They could not have been more than about two days old, as the spot had been examined thoroughly two days previously.

Metamorphosis.—On December 20th the tadpoles, still in the egg capsule, measured 5 mm. They were then a light brown above, with an elongate whitish yolk sac beneath. There were two tiny sucker-like arrangements beneath and in front of the head, by means of which they adhered to the outside of the capsule when they were liberated.

December 22nd.—Total length 7 mm., tail 4·5 mm.

The eyes were visible at this stage as black spots ; the suckers had diminished in size and had moved towards the tip of the snout. The head had considerably broadened and taken shape ; the tail had developed considerably and was covered with tiny black spots, as was also the head ; the external gills were visible as tiny white branches on either side (fig. 2).

December 23rd.—Total length 8 mm., tail 5 mm.

The anal canal had reached the margin of the tail fin ; the external gills had disappeared ; the coils of the gut were beginning to form ; the sucker had dwindled down to two slits (fig. 4).

December 25th.—Total length 8·5 mm., tail 6 mm.

At this stage three pairs of gill slits were visible ventrally through the transparent skin (fig. 5), but no sign of the spiraculum. The mouth was not yet formed ; the body was becoming pigmented and assuming its peculiar shape.

December 27th.—Total length 9 mm., tail 6·5 mm.

The whole dorsal surface and tail were covered with tiny black spots; the gut showed signs of functioning; the mouth was now formed and spiraculum visible.

December 29th.—Total length 10·5 mm., tail 6·5 mm.

The head had practically assumed its peculiar shape, the front portion

Fig. 2.

becoming more transparent. The two suckers were still present in the shape of two tiny spots on either side directly in front of the head. The nasal openings and the pineal spot were also very distinct.

December 31st.—Total length 15 mm., tail 9·5 mm.

The legs began to appear as tiny white buds. The eyes stood out very prominently in the otherwise transparent head.

Fig. 3.

February 20th.—Total length 34 mm., tail 23 mm.

This was their greatest length. From this stage onwards the growth was rather slow and the specimens for some reason did not thrive; perhaps there was something lacking in the water to their peculiar mode of life.

March 10th.—Total length 30 mm., tail 16 mm.

The shape of the body had now altered considerably (Pl. IX, fig. 4), and had become more or less opaque; tail shorter and more robust; the hands could be seen beneath the skin folded across the abdomen; the

spiraculum had become more and more enlarged to enable them to be thrust through.

The mouth still persisted; remaining two specimens died at this stage.

Tadpole (Pl. IX, figs. 1 and 2).—Length of body once and two-ninths

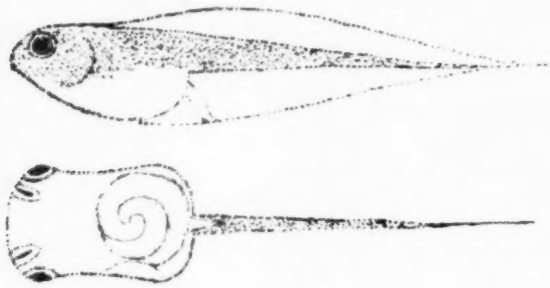


Fig. 4.

the width; a little more than half the length of the tail. Nostrils nearer to the end of the snout than to the eyes; the distance between them one-eighth the distance between the eyes. Eyes perfectly lateral, visible from above and below. Spiraculum on the mid-ventral line at the posterior

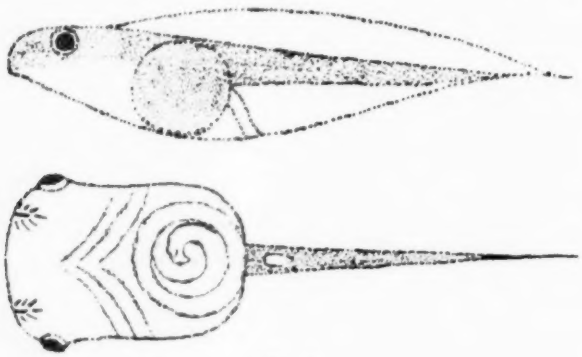


Fig. 5.

extremity of the body; just in front of the anus. Anal opening median, smaller than the spiraculum. Tail over three times as long as deep, tapering to a thread-like point; both crests very slightly convex, the lower nearly three times as deep as the upper, which does not extend upon the back. The depth of the muscular portion of the tail at its base about one-fourth the total depth.

No beak, no papillae surrounding the mouth, no labial teeth. The mouth (Pl. IX, figs. 1, 2, and 3) is different from that of any tadpole known to the writer, and is strikingly like that of a fish. In life it is constantly opening and shutting, as in the case of ordinary respiration in fishes. Probably water enters the mouth, is driven over the gills, and expelled through the opening just in front of the anus, which, for the time being, I am calling the spiraculum. The body has a kite-shaped outline when viewed dorsally.

Colour.—Body transparent except in the neighbourhood of the intestine; covered above and at the sides to a little below the eyes with minute black and gold spots.

They remain motionless for hours except for the incessant vibration of the tip of the tail; and they invariably remain so near the surface of the water that their breathing movements are perceptible thereon. They were never seen to nibble, so the contents of the intestine were examined microscopically and found to consist of diatoms and minute algae in great abundance.

BUFO.

About seven species of the genus Bufo occur in South Africa; little is known of any of them beyond cut-and-dry descriptions of spirit specimens. The author has worked out the life-history of one of the above, and partially that of another.* The following account attempts to describe the habits and life-history of a third.

Habits.—Bufo Carens, the subject of the present account, has a fairly wide distribution, being found at various places between 28° 40′ and 1° S. It was observed breeding in great numbers at Lobatsi during December 1924. The vocal sac is larger than that of *Bufo regularis* when fully inflated: the call resembles the resonant sound made by drawing a bow across the strings of a double-bass. The male grasps the female, as in the case of *Bufo regularis*, in the axillary region, pressing the hands well into the arm-pits, and will allow himself to be picked up without releasing his hold. Males are, moreover, so amorous that, failing a female, they will grasp another male. Evidently they breed day and night just after rain. The writer has seen eight pairs in embrace within an area of two square yards, while there were several calling males unpaired at the same place at noon. The call, though deep and sonorous, can be heard only at a distance of from eighty to one hundred yards.

The eggs, 2·5 mm. in diameter, almost completely black except for a tiny dark-grey spot on the lower pole, are laid in two strings, being in a single row when pulled taut, but forming themselves into two rows when

* Trans. Roy. Soc. S. Afr., iii, 1913, pt. 1, pp. 173 and 174.

the tension is released. They are twined round stones and weeds near the water's edge.

Metamorphosis.—A quantity of eggs were laid at one spot on the night of December 16th. On the following day (December 17th) the embryo measured 3 mm.

December 19th.—Total length 8 mm., tail 3·5 mm.

The eyes were visible as tiny black spots. The development of the tail and tail fin in two days was remarkable. At this stage they were still adhering in masses to the jelly-like capsule.

December 20th.—Total length 9 mm., tail 4 mm.

The external gills were very prominent and the intestine had begun to form. No mouth parts were yet visible.

December 22nd.—Total length 12 mm., tail 7 mm.

The gut, anal opening, mouth parts, and eyes visible. The tail fin was well developed, the external gills were fast disappearing through tiny slits in the sides. There appeared a horseshoe-shaped fold on the head extending from the eyes to more than half-way back on the head, fringed with a thin membrane like the tail fin.

December 25th.—Total length 14·5 mm., tail 9·5 mm.

Spiraculum noticed for the first time ; legs began to appear as tiny buds.

January 20th.—Total length 38 mm., tail 12 mm.

This was their maximum length. The arms could be seen moving beneath the skin.

January 23rd.—Total length 31 mm., tail 18 mm.

The left arm came through during the day, and the right one during the succeeding night.

January 24th.—They began to leave the water, tail still very long (21 mm.), and hampered them in their movements.

January 26th.—The tail now completely absorbed, and the tiny toads were struggling to get out of the tank. The peculiar fold on the head persisted for a considerable time after the metamorphosis was completed. Tiny toads two months old showed a slight indication of it in the shape of a line at the back of the head.

Tadpole (Pl. VIII, figs. 1 and 3).

The length of the body is once and two-thirds the width, less than half the length of the tail : nostrils nearly on a level with the front of the eyes. Eyes on the upper surface of the head ; the distance between them nearly twice as great as the distance between the nostrils, and equal to the width of the mouth ; surrounded by a triangular-shaped depression. Spiraculum on the left side directed backwards but not upwards ; about equidistant from either extremity of the body but scarcely visible except in preserved specimens. Anus median, about as large as the spiraculum. Tail nearly

three times as long as deep; broadly rounded at the end; both crests about equal in depth; the top one nearly straight, the lower one slightly convex. The depth of the muscular part at its base two and one-third times less than the total depth. Upper crest not extending as far forward as the spiraculum. A horseshoe-shaped fold or fin on the head (Pl. VIII, fig. 3), 1·5 mm. at its deepest part, and tapering towards the eyes, extending from the eyes to beyond the middle of the head, concave side facing the front. Its character the same as that of the tail fin.

Beak white (Pl. VIII, fig. 2), edged with black. Lips with papillae only at the sides; upper and lower edges toothed, the series of labial teeth being $\frac{2}{3}$.

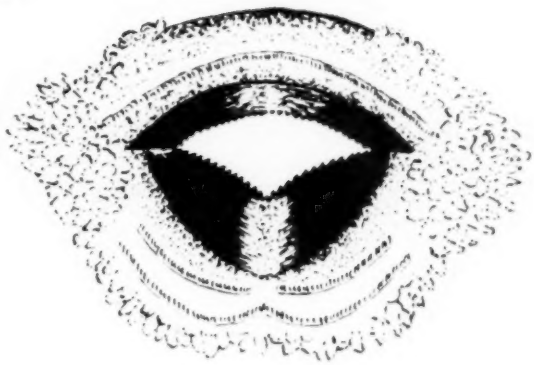
Colour.—A shiny black, caudal crests dark greyish.

The tadpoles form themselves into a colony as soon as they leave the egg-capsule, and remain so until the metamorphosis is complete. They may be seen in a black compact mass in a pool, rushing to the surface for air, and then down again. At other times they swim round the pool in a black array about ten inches broad and several yards long, like an army of soldiers on the march. They are evidently capable of living in very stagnant water, and the adults are by no means particular as to where the eggs are laid. Every pool, no matter how small, has its colony of tadpoles, and large compact masses may even be seen drying up in desiccating ones. As soon as the arms come through they leave the water in a body and pile themselves together in damp, shady crevices on land; the tail now becomes quickly absorbed.

As stated above, the head is provided with a peculiar soft, flabby, horseshoe-shaped fold or fin-like structure, which is in constant more or less wavy motion while the tadpole is swimming (Pl. VIII, fig. 1), but when it is at rest the fin lies flat on the head (Pl. VIII, fig. 3).

Occasionally when the water was very fetid it was noticed that the tadpoles swam very near the surface, the fold serving as a float for the head. Possibly this may be a mechanism for sustaining the head on the surface under adverse circumstances.

As far as the writer is aware, this is the first time that a tadpole has been described with such an appendage.



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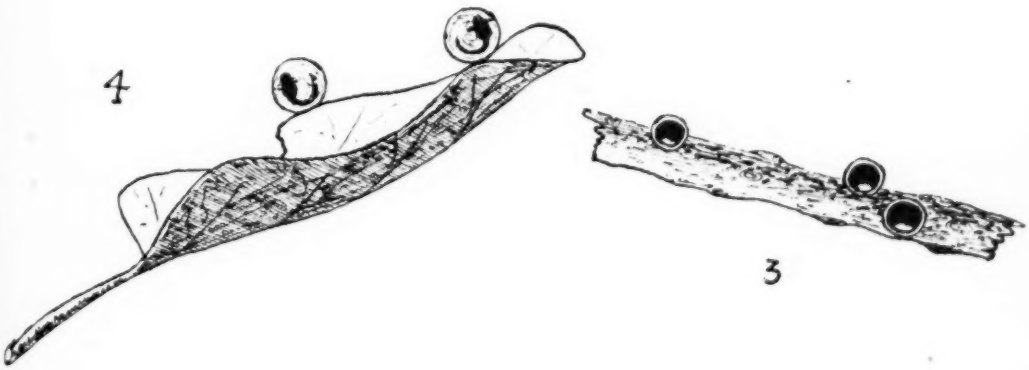

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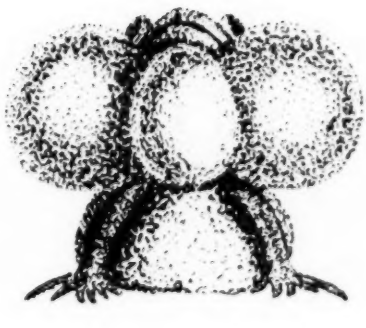

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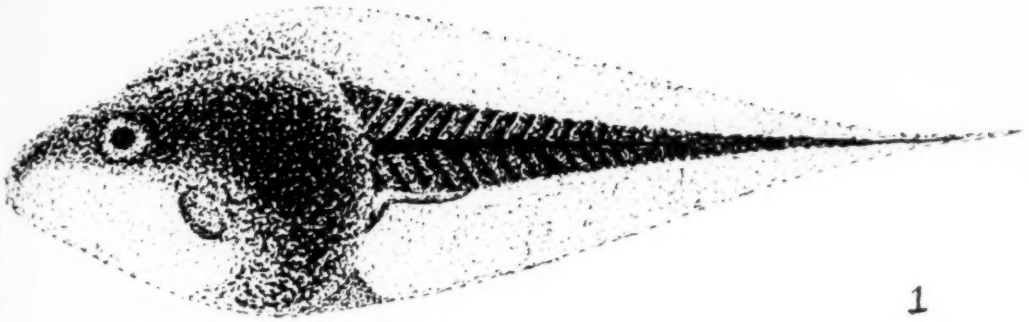

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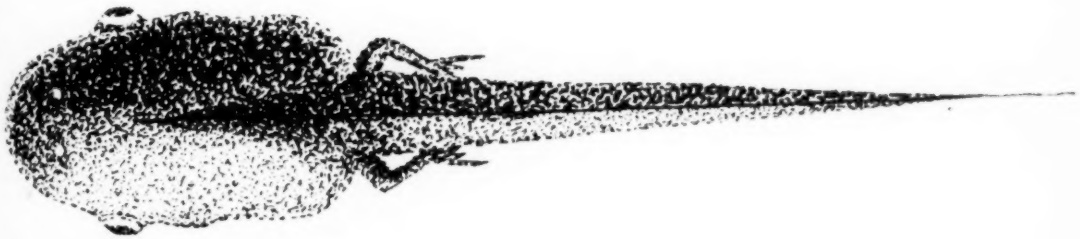

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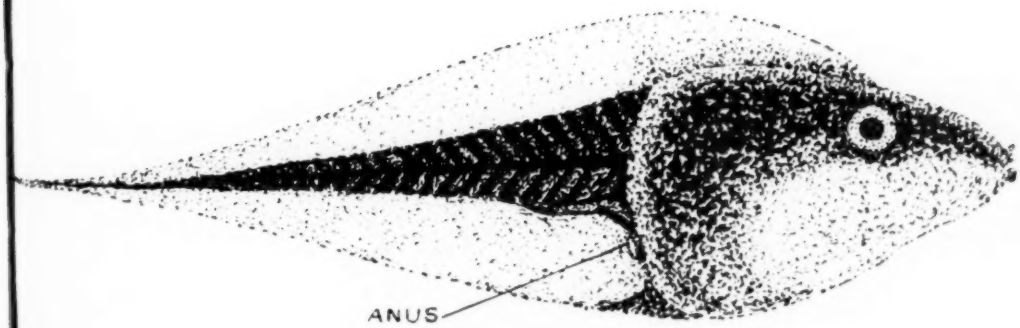

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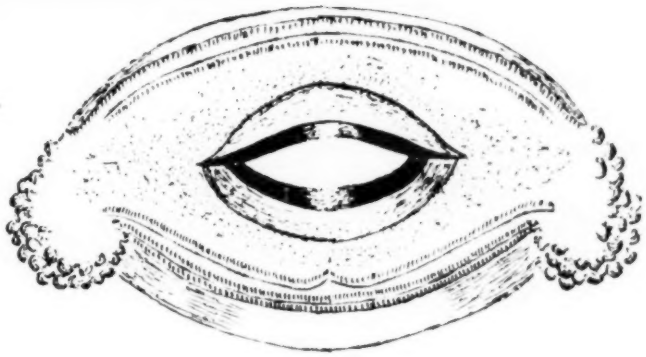

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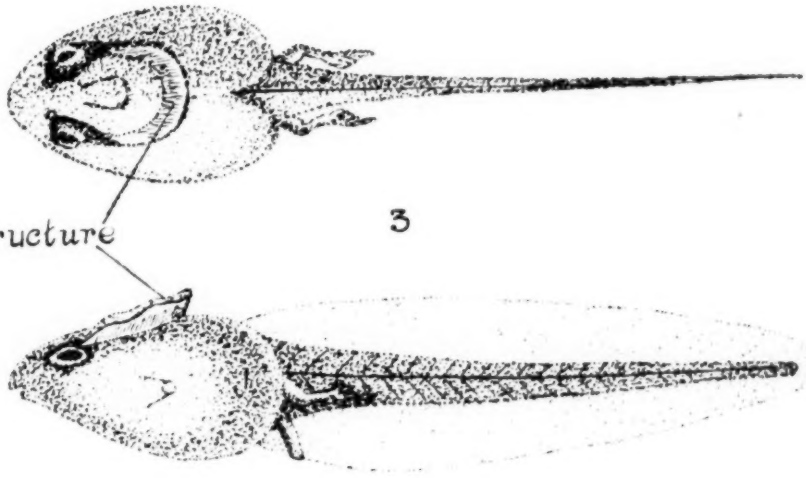

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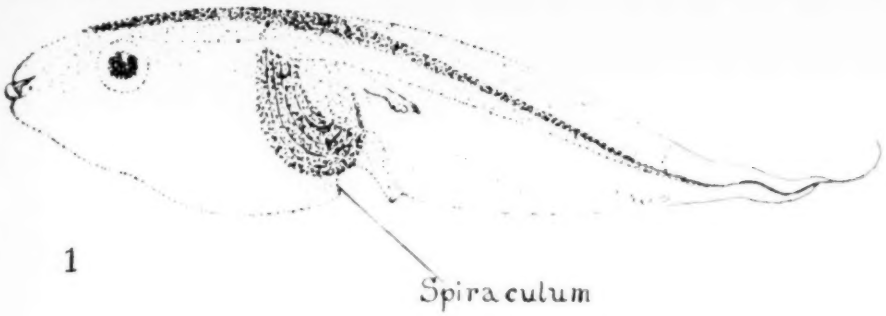

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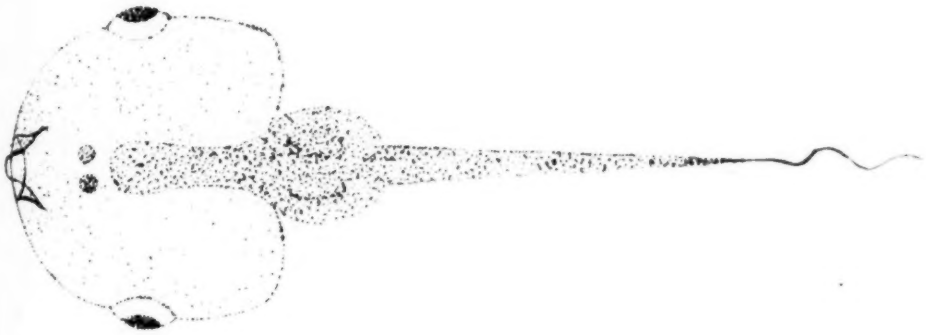

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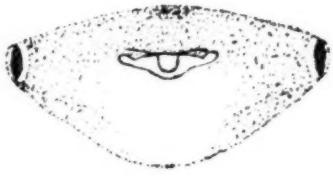

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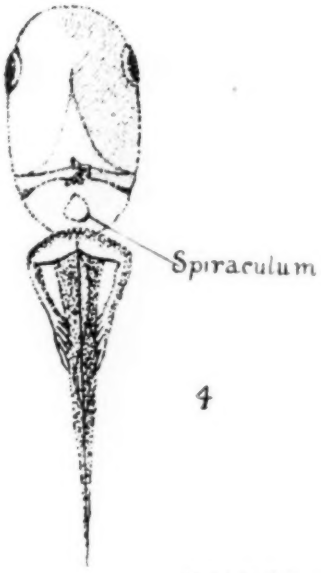

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REPORT ON A COLLECTION OF CRUSTACEA FROM PORTUGUESE EAST AFRICA.

By K. H. Barnard, D.Sc., F.L.S., F.R.S.S.Afr.

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(With Plates X–XI.)

The collection herein reported upon was made during the course of the Marine Survey of Portuguese East Africa undertaken for the Mozambique Government by Dr. J. D. F. Gilchrist, to whom I am indebted for the opportunity of examining the collection.

Although not very large, the collection contains some interesting forms, and much credit is due to the Portuguese officers—Lieut.-Comm. Bello, Chief of the Marine Staff, and Lieut. Amaral, Port Captain, Delagoa Bay—who were concerned with the operations of the Survey; and to Mr. W. J. Copenhagen, who acted as biologist on board the Survey ship.

The Crustacea of Portuguese East Africa are comparatively little known, especially in the region around Delagoa Bay. From the works of Bianconi, Hilgendorf, Lenz, Miers, and Kemp a list of about 140 species can be obtained. My own collections, made on behalf of the South African Museum, at Delagoa Bay, Inhambane, and Mozambique in 1912, yielded 29 species not before recorded. Of these 8 were described by Stebbing,* 9 by myself.† The remaining 12 have been incorporated in the present report for the sake of making the fauna-list of Portuguese East Africa as complete as possible.

The present collection contains 57 species, of which 14 have been previously recorded, bringing the total number of species on the fauna-list up to 211. This number is only about one quarter of the number of species recorded from South Africa south of 27° S. lat., and evidently represents but a small part of the real fauna-list.

* Stebbing, Ann. S.A. Mus., xv, pt. 1, 1914; *ibid.*, pt. 2, 1915; *ibid.*, xviii, pt. 4, 1921; *ibid.*, xix, pt. 1, 1924.

It should be noted that the specimens recorded under the name "*Actaea parvulus* Krss." do not belong to that species, but comprise specimens of *Actaea rüppelli* Krss., *Xanthodes lamarcki* M. Edw., and *Carpilodes bellus* Dana, according to the more recent identifications of Dr. Th. Odhner.

† Barnard, Ann. S.A. Mus., x, pt. 7, 1914; *ibid.*, pt. 11, 1914; *ibid.*, xv, pt. 3, 1916; *ibid.*, xx, pt. 1, 1924.

The results of the Survey are valuable in showing that there is still much to be done, especially in the deeper waters, in this region. The capture of a crayfish of the genus *Palinustus*, hitherto known only from the West Indies, and of three Indo-Pacific forms not reported since their capture by the "Challenger," are striking results, considering the comparatively short period during which the trawling vessel had been in commission. They indicate that a continuance of the Survey would yield still more interesting results.

The 43 new records are listed below, together with those in the South African Museum collection, the latter being indicated by an asterisk.

BRACHYURA.

**Huenia proteus* (de Haan) . .	Delagoa Bay.
Hyastenus diacanthus (de Haan) var. *spinosus* . . .	,,
**Macropodia formosa* Rath . .	,,
**Dehaanius macleaii* (Krss.) . .	,,
Cyrtomaia murrayi Miers . .	Label lost.
Platymaia wyville-thomsoni Miers .	26° 3′ S. 33° 4′ E. 290 m.
Actaea savignyi (M. Edw.) . .	Delagoa Bay.
**Xantho hydrophilus* (Hbst.) . .	,,
**Neptunus argentatus* (White) .	,,
**Thalamita prymna* (Hbst.) . .	,,
Charybdis merguiensis (de Man) .	,,
Carcinoplax longimanus (de Haan)	25° 17′ S. 33° 29′ E. 117 m.
**Typhlocarcinus rubidus* Alck. .	Delagoa Bay.
Plagusia squamosa (Hbst.) . .	,,
**Uca vocans* (M. Edw.) . .	,,
Elamena mathaei (Desm.) . .	,,
Calappa flammea Hbst. . .	25° 45′ S. 33° 3′ E. 58 m.
Mursia bicristimana Alck. & And.	26° 3′ S. 33° 4′ E. 290 m.
Leucosia marmorea Bell . .	26° 17′ S. 33° 10′ E. 415 m.
**Philyra punctata* Bell . . .	Chinde.
Dorippe lanata (Linn.) . .	26° 17′ S. 33° 10′ E. 415 m.
Homola andamanica Alck. . .	26° 3′ S. 33° 4′ E. 290 m.
Latreillopsis alcocki Stebb. . .	25° 59′ S. 33° 6′ E. 312 m.
Latreillia elegans Roux . .	25° 55′ S. 33° 4′ E. 37 m.
**Clibanarius padavensis* de Man .	Delagoa Bay.
**Porcellana dehaani* Krss. . .	,,
Munida incerta Hend. . .	See below.
Emerita emeritus (Linn.) . .	Delagoa Bay. Inhambane.

MACRURA.

**Calliadne savignyi* (Strahl) . .	Delagoa Bay.
Scyllarus sordidus (Stmpsn.) .	See below.
,, *tuberculatus* (Bate) .	,,
Ibacus peroni (Leach) . .	,,
Thenus orientalis (Lund) . .	Delagoa Bay.
Palinurus gilchristi Stebb. var. *delagoae* nov. . . .	See below.
Palinustus mossambicus n.sp. .	,,
Nephrops andamanica Wood-Mason	,,
Penaeus japonicus Bate . .	Delagoa Bay.
,, *monodon* Fabr. . .	,,
Pontophilus megalocheir (Stebb.) .	See below.
Eupalaemon sundaicus (Heller) .	Delagoa Bay.
Glyphocrangon gilesi Wood-Mas. var. *dentatus* nov. . . .	See below.
Anchistus inermis (Miers) . .	Delagoa Bay.
Alphaeus crassimanus Heller. .	,,
,, *rapax* de Haan. . .	,,

STOMATOPODA.

Squilla latreillei (Eyd. & Soul.) .	Delagoa Bay.
,, *nepa* (Latr.) . . .	Exact locality lost.
Pseudosquilla ciliata (Latr.) .	Delagoa Bay.
Gonodactylus glabrous Brks. .	,,

ISOPODA.

Meinertia imbricata (Fabr.) . .	Delagoa Bay.
Cymothoa borbonica Sch. & Mein. .	,,
Epipenaeon japonicum Th. . .	,,

AMPHIPODA.

Leucothoe spinicarpa (Abilg.) .	Delagoa Bay.

OSTRACODA.

Crossophorus africanus Stebb. .	25° 59′ S. 33° 31′ E. 540 m.

CIRRIPEDIA.

Octolasmis warwicki Gray . .	On various crabs.
Balanus astacophilus n. sp. .	See below.

Family GALATHEIDAE.

Munida incerta Hend.

1888. Henderson, Challeng. Rep., xxvii, p. 130, pl. xiii, fig. 4.

The specimens agree with Henderson's description, but are considerably larger and have a relatively shorter rostrum.

The rostrum is just over one-third the length of carapace. The inner apex of the 2nd peduncular joint of the antenna ends in a slender spine with 1–2 spinules at its base; the outer apex also has a spine, but smaller than the inner one.

In the single "Challenger" specimen both chelipeds were lost. In these specimens they are elongate, subcylindrical, and squamose. The 4th joint is spinose along both upper margins and along the inner margin; the 5th likewise but more feebly spinose; the 6th has only a few short spines differentiated from the squamae. The 6th joint, including the immobile finger, about 3 times as long as 5th. Both fingers elongate, straight, slender, slightly longer than the palm, their inner margins in contact throughout; close to the base there are 2 teeth interlocking with those on the opposite finger, the rest of the inner margins being finely denticulate, with a few slightly larger denticles on the immobile finger. One specimen, which has only one cheliped, lacks the basal teeth on the fingers, the whole inner margin being straight.

Length and *breadth* of carapace 28 mm., length of rostrum 10 mm., of cheliped 104 mm.

Colour.—Pale salmon red.

Locality.—25° 56′ S., 32° 52′ E., 17 metres, sand and shell.

Distribution.—Philippine Islands, 250 fathoms.

Family SCYLLARIDAE.

Scyllarus sordidus (Stmpsn.).

(Plate X.)

1888. Bate, Challeng. Rep., xxiv, p. 66, pl. ix, fig. 3.

A ♂ specimen, total length 65 mm., length of carapace 25 mm., agrees with Bate's figure and description. The colour is rusty-red, paler towards end of abdomen, eyes dark maroon.

Locality.—26° 3′ S., 33° 4′ E., 290 metres, fine sand.

Distribution.—Hong Kong (Stimpson), Arafura Sea, 140 fathoms (Bate).

Scyllarus tuberculatus (Bate).

(Plate X.)

1888. Bate, Challeng. Rep., xxiv, p. 70, pl. x, figs. 1, 2.

1920. Stebbing, Ann. S. Afr. Mus., xvii, pt. 4, p. 267 (*Thenus orientalis* non Lund).

An ovigerous ♀ specimen, total length 58 mm., length of carapace 21 mm., agrees with Bate's figures and description. The peduncle of the antennule, however, only reaches to the end of the last joint of the antenna, its basal joint is distinctly the longest, the 3rd shorter than the 2nd.

Colour.—General colour red, paler towards end of abdomen, mottled with paler red and white, most of the tubercles have white tips, outer margin of 2nd joint of antennae and the smooth dorsum of 1st abdominal segment violet.

Locality.—26° 17′ S., 33° 10′ E., 415 metres, sand and shell.

Distribution.—Between New Guinea and Australia, 49 fathoms (Bate).

I have also examined a young specimen, 18 mm. total length, which was recorded by Stebbing (*loc. cit., supra*) as *Thenus orientalis* from off the Zululand coast. It is obviously a young *S. tuberculatus*, though it is less prominently rugose and tuberculate; the distinctive knob on the 3rd abdominal segment is merely indicated. On the ventral surface there is a tubercle on the 5th thoracic sternite only.

Ibacus peronii (Leach).

Locality.—25° 24′ S., 33° 25′ E., 310 metres, sand and mud; 26° 3′ S., 33° 4′ E., 290 metres, fine sand.

Family PALINURIDAE.

Palinurus gilchristi Stebb.

var. *delagoae* n.

(Plate XI.)

This form is so closely allied to *gilchristi* that I have hesitated to give it specific rank. After an examination of numerous examples of typical *gilchristi* I have failed to find any hint of variation in regard to the two characters which differentiate the two forms, and therefore I had almost decided to give the present one specific rank.

Later, however, I was able to examine through Dr. Gilchrist's kindness two examples of the crayfish found on the Natal coast. These examples,

though distinctive in themselves, formed a transition between typical *gilchristi* and the Delagoa form.

It therefore seems advisable to treat the Natal and Delagoa forms as local races and rank them as varieties of *gilchristi*.

The Delagoa Bay variety resembles *gilchristi* in nearly all particulars; the two most important exceptions being the following:—

In *gilchristi* the 2nd–5th abdominal segments have the transverse furrow interrupted in the centre by a low, but distinct, median keel. This keel is marked on either side by a shallow groove. Both these grooves and the transverse grooves are filled up with a thick, short pilosity which gives a distinctive H-shaped marking on the 2nd–5th segments.

In *delagoae* the transverse grooves are very shallow, with a few setae only in the one specimen and none at all in the other. In particular the grooves on either side of the median keel are non-existent.

The second character forms an even more sharply defined difference between the two forms. In *gilchristi* the legs are more or less triquetral in cross-section, especially the 4th and 5th joints. The flattened outer or posterior sides of these joints are also very slightly grooved, and the grooves are occupied by a strip of short, close pilosity. In *delagoae* the legs are subcylindrical and there is no trace of the pilose strips.

These two features seem sufficiently clear-cut and distinctive to justify at least varietal rank for the Portuguese East African form.

It will be noticed that *delagoae* resembles *vulgaris* in the first feature, but differs from it in the second feature.

As regards other characters, *delagoae* very closely resembles *gilchristi*. It has the 3 close-set pairs of spines in the middle line of the carapace in front of the cervical groove, and the 4 distinct lines of spines behind the cervical groove which differentiate it from *vulgaris*. But the whole ornamentation of the body is much less prominent than in *gilchristi*, and the little groups of setae around the bases of the spines which give a squamose appearance to *gilchristi* are almost or quite obsolete in *delagoae*.

The same remarks apply to the under surface, the sternal plate being much smoother and the patch of spines on the 6th abdominal segment in ♂ reduced to 2 very small and blunt points.

The eyes in *delagoae* are slightly larger proportionately than in *gilchristi*.

The ♂ is larger than any specimens of *gilchristi* that I have seen.

Colour (as preserved).—Pinkish or mauve, the legs and antennae banded with white or cream as in *gilchristi*, the abdomen with white marbling and oblique stripes on each segment very much as in *gilchristi* and *vulgaris*.

Length of carapace 94 mm.; total length from front of carapace to end of telson 244 mm.

Locality.—25° 58′ S., 33° 5′ E., 228 metres, sand and shell.

var. *natalensis* n.

1921. Gilchrist, Fish. Mar. Surv. Rep., No. 1 (1920), pp. 5, 16, pl. vii (localities).

1922. *Ibid.*, No. 2 (1921), p. 1 (localities).

1925. Calman, *ibid.*, No. 3 (1925), p. 21.

This variety resembles var. *delagoae* in size, in the smooth subcylindrical legs, the smooth sternum, and the 2 small points on the under surface of the 6th abdominal segment.

The dorsal ornamentation of the abdomen, however, is intermediate between typical *gilchristi* and var. *delagoae*. The grooves are better developed than in the latter, but are very feebly pilose, or quite glabrous. The carapace also is more squamose than in *delagoae*.

Locality.—Natal coast, from off Umkomaas River in the south as far north as off Tugela River (as far as yet ascertained); and off Delagoa Bay, 100–260 fathoms.

The three forms thus constitute a series, but with the varieties *natalensis* and *delagoae* more closely related to one another than either of them is to *gilchristi*. Size and the character of the legs are distinctive features.

The examination of a large amount of material might show that *natalensis* should be merged into *delagoae*, and the latter raised to specific rank. For the present I think that the conferring of varietal names will sufficiently meet the case.

Typical *gilchristi* has been found from False Bay to Algoa Bay in comparatively shallow water of 30–60 fathoms. In the deeper water to the north a distinctive race seems to be in process of differentiation.

Gen. Palinustus M. Edw.

1880. A. Milne-Edwards, Bull. Mus. Comp. Zool. Harv., viii, p. 66.

Ophthalmic segment completely uncovered. Frontal spines in the form of small flattened horizontal plates projecting over the ocular peduncles. Antennules elongate, with short flagella.

This genus was proposed for a West Indian crayfish captured by the "Blake." It has apparently not been met with in other parts of the world. Its occurrence off the coast of Portuguese East Africa is therefore exceedingly interesting, and forms a parallel to the distribution of *Palinurus longimanus*, which was originally described from the West Indies and afterwards (as var. *mauritianus* Miers.) from Mauritius.

The present specimen, however, is the representative of a species quite distinct from *P. truncatus* M. Edw.

Palinustus mossambicus n. sp.

(Plate XI.)

Carapace with fine granules and tubercles, and covered with a short fine pilosity. Frontal margin truncate, with a pair of spines (no median rostral point). Between these and the cervical groove 4 pairs of spines, diverging posteriorly. Frontal spines projecting over the free portion of the ocular peduncle, front margin denticulate, outer lateral margin with 2–3 spinules. Behind these 2 smaller spines. Outer margin of orbit with 3 long slender curved spines. A median and dorso-lateral irregular line of tubercles somewhat larger than the surrounding ones. A deep submarginal groove on posterior margin.

Abdomen shallowly and closely pitted, with sparse short pilosity. 2nd–5th segments with a low rounded median longitudinal keel. 1st–5th segments each with a transverse groove near the base and another near the posterior margin, the latter interrupted by the median keel, except on the 1st segment, where it is continuous. Both grooves and also the posterior margin of each segment with thick fringe of setae. 6th segment with a median longitudinal groove flanked on either side by a submedian groove which curves round outwards and laterally. A few small tubercles on the 6th segment and on basal half of telson.

Pleura of segments 2–4 ending in 2 subequal points.

Ophthalmic segment with 4 little spinules on its anterior margin.

Antennal segment narrow, smooth, except for a few setae.

Thoracic sterna each with a pair of small blunt tubercles near the median line, except the 4th, which has a single median tubercle. Abdominal sterna of segments 1–5 with a few (4–6) small sharp spines on posterior margins, sternum of 6th segment with about 8 on either side of the median line. Telson with a pair of spines at base in front of anus.

Antennule, 1st joint longer than carapace, almost equal to rest of antennule including the flagella; 2nd joint about $\frac{1}{3}$ the 1st and $\frac{1}{2}$ the 3rd joint; flagella short, equal to 2nd peduncular joint. The whole peduncle covered with short stiff setae.

Antenna, peduncle spinose and setose, lower margin with a fringe of long plumose setae; flagellum on both sides missing, the few remaining basal joints, however, with short, stout spine-setae and a fringe of plumose setae on lower margin.

Third maxilliped and all the legs with long, stiff, outstanding hairs. 4th–7th joints grooved on outer side, the groove on 4th joint filled with a close, short pilosity. Third maxilliped reaching to end of 2nd peduncular joint of antenna and to 4th joint of 2nd leg. 1st leg a little longer than length of abdomen plus telson; 4th leg a little longer than 1st, 3rd leg longer still

and equal to distance from front of carapace to end of indurated portion of telson. 2nd and 5th legs on both sides missing.

Genital opening on 5th leg forming a prominent papilla, with a flap closing the opening and a little brush of stiff setae on inner margin.

Pleopods with well-marked fringe of setae.

Indurated portions of uropods with inner margins spinulose.

Length of carapace 30 mm., total length from front of carapace to end of telson 95 mm.

Colour.—Salmon-red, a deeper red (crimson) band across front of carapace; abdominal segments with white spots on posterior margins, an oblique white lateral line on segments 2–5, and lateral points of segments 2–5 white; 1st joint of peduncle of antennule with basal, median, and apical white bands, 2nd and 3rd joints with apical white bands only, flagella crimson; legs spotted and banded with white, the greater part of the 5th–7th joints being white; telson and uropods with a thin red marginal line.

Locality.—25° S., 33° 10′ E., 406 metres, mud.

Family NEPHROPSIDAE.

Nephrops andamanica W. Mas.

1894. Wood Mason, Ann. Mag. Nat. Hist., p. 226, and Illustr. Zool. Investigator, pl. iv, fig. 1 (1892), and pl. viii, fig. 5 (1894).

1916. de Man, Siboga Exped. Monogr., xxxix, *a*2, p. 99, pl. iii, fig. 15.

1921. Gilchrist, Fish. Mar. Surv. Rep., No. 1, p. 16, and Annexure A (recorded).

1922. *Ibid.*, No. 2 (1921), Annexure A, p. 7, etc. (localities).

Locality.—25° 28′ S., 33° 31′ E., 420 metres, sand, shell, and mud.

Also taken by the s.s. "Pickle" off Delagoa Bay, 275 fathoms, and in several localities in the neighbourhood of Durban and Tongaat River in 102–460 fathoms.

Distribution.—Andaman Sea ("Investigator"), Bali Sea ("Siboga").

Family CRANGONIDAE.

Pontophilus megalocheir (Stebb.).

1915. Stebbing, Ann. S. Afr. Mus., vol. xv, pt. 2, p. 71, pl. lxxix.

A single specimen, 23 mm. long, from Delagoa Bay, has led me to examine the type of *Philoceras megalocheir*, especially in reference to the remarks of Kemp (Rec. Ind. Mus., xii, 8, p. 372, 1916).

In the first place it may be remarked that the specimens from 33° 13′ S., 27° 39′ E. (S.A.M., No. A1316) should be assigned to *P. hendersoni* Kemp. They are quite typical examples, except that I find the apex of the antennal

scale is variable, and, therefore, cannot be used to differentiate *magealocheir* from *hendersoni*.

The type of *megalocheir* (S.A.M., No. A1317) consists of the dried abdominal segments and microscope preparations of the carapace and appendages.

No indication of the projection on the 3rd abdominal segment can be seen in the type, nor in the Delagoa Bay specimen. In the latter the sternal spine between the chelipeds is present but there are no carinae ending in spines on the last four sterna.

The apex of the antennal scale in the Delagoa Bay example resembles that of *hendersoni* as figured by Kemp.

The telson of the type, contrary to Stebbing's description and figure, resembles that of *hendersoni*. And the Delagoa Bay specimen also agrees in this respect.

There are, therefore, apparently only two characters by which to separate *hendersoni* and *megalocheir*: the greater size and the absence of the abdominal tubercle in the latter.

Family GLYPHOCRANGONIDAE.

Glyphocrangon gilesii W. Mas.

1891. Wood Mason, Ann. Mag. Nat. Hist., p. 193.
1894. *Ibid.*, Illustr. Zool. Investigator, pl. vii, fig. 4.
1899. Alcock, Cat. Ind. Deep-sea Crust., p. 132.

var. *dentata* n.

Distinguished from the typical form by the posterior half of the 2nd or subdorsal crest being distinctly and sharply tridentate.

Length of rostrum 24 mm., of carapace 22 mm., of abdomen 52 mm.

Locality.—25° 59′ S., 33° 31′ E., 540 metres, mud and sand.

CIRRIPEDIA.

Family BALANIDAE.

Balanus (*Solidobalanus*) *astacophilus* n. sp.

Shell moderately solid, conical, smooth, orifice only slightly notched. Base calcareous, thin, radiately ribbed. Parietes smooth, very finely striate, growth lines fine but distinct, internally with several ribs, basal edges crenulate. Radii broad, transversely grooved, summits straight and nearly parallel with base, edges crenulate. Alae broad, summits slightly oblique.

Scutum not very thin, growth lines forming rather widely spaced deep

grooves, with finer intervening lines (cf. *B. hawaiensis* Pils.), the occludent margin consequently strongly toothed, a prominent articular ridge extending nearly ¾ of the length of the tergal margin, no adductor ridge, scar of adductor muscle faint.

Tergum with growth lines, faint but more distinct on the band leading to the spur and especially on the scutal margin, groove very shallow, spur short but broad, well defined from basal margin, articular ridge and crests for depressor muscles well marked.

Labrum with 4–5 teeth on the straight margin on either side of the median notch. Maxilla and mandible as in *hawaiensis*, but the mandible with 5 teeth besides the trispinose lower angle.

Cirri : 1st with unequal branches of 8 and 11 joints, 2nd with slightly unequal branches of 8 and 9 joints, 3rd with somewhat unequal branches of 9 and 10 joints, 4th–6th with ca. 20 joints, each joint with 3 large pairs and one small pair of spines on inner margins ; no recurved teeth on any of the cirri. Penis extremely long, almost glabrous.

Length of base 5 mm., of orifice 3·5 mm. ; *height*, 4 mm.

Colour.—Chalky white.

Locality.—25° 28′ S., 33° 31′ E., 420 metres, on legs of *Nephrops andamanica*, several specimens.

This species is closely related to *B. hawaiensis* Pilsbry, 1916, but differs in the form of the parietes and tergum.

Scyllarus sordidus (Stmpsn.).

Scyllarus tuberculatus (Bate).

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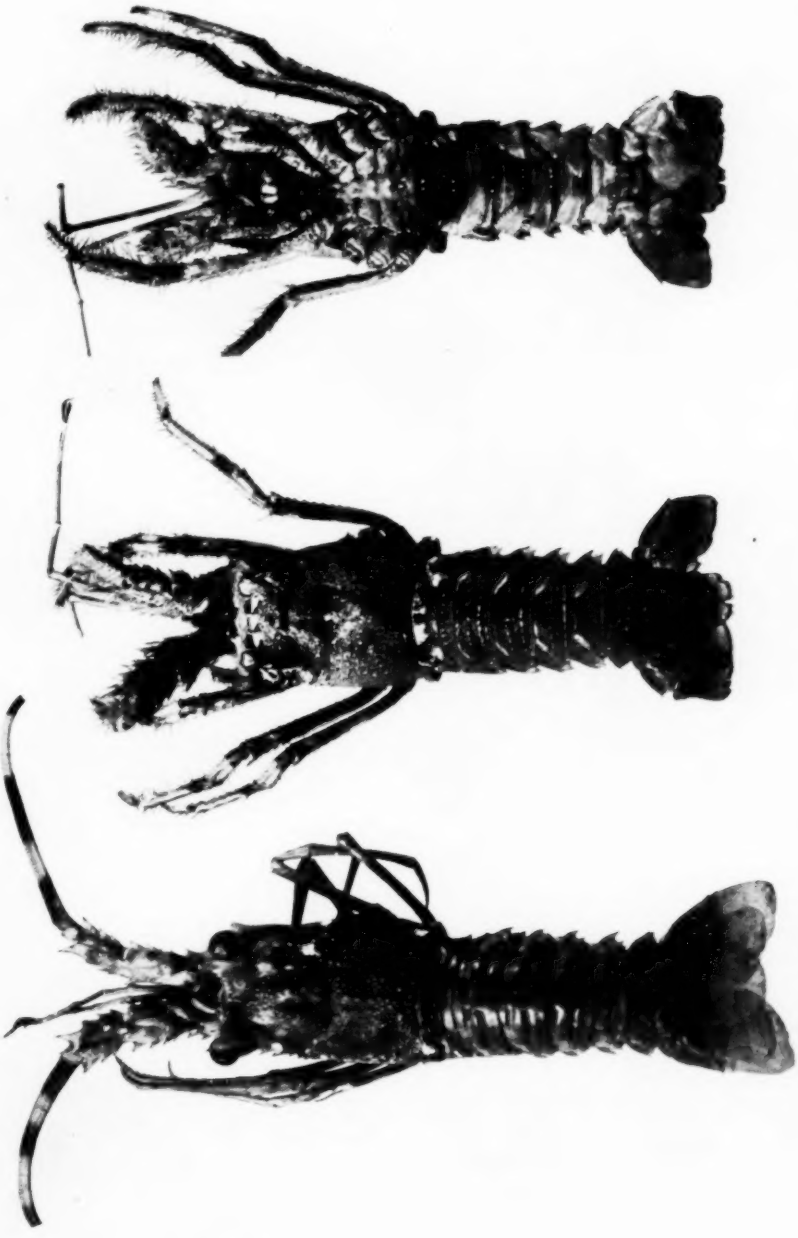


Palinustus mossambicus n. sp.

Palinurus gilchristi Stebb.
var. *delagoæ* n.

Neill & Co., Ltd.

COLOUR AND CHEMICAL CONSTITUTION.

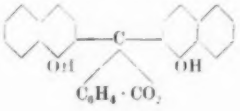
Part XX.—Some Residual Problems.

By James Moir.

A. The Naphtholphthaleins.

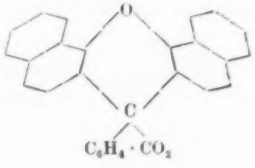
Commercial naphtholphthalein, which shows a band at λ 662 (see Part I, 1917), is a mixture of two substances, one of which is white and gives an indigo alkali solution (with λ 650). This one is not easily converted into α-naphthafluorane by sulphuric acid.

The other substance, present only in small quantity, is *brown* when free and gives a dark green (emerald) solution in alkali (with λ 671). The latter is much less soluble in 50 per cent. alcohol than the former is. It dissolves in concentrated sulphuric acid with a green colour (λ about 625), which rapidly goes pink owing to conversion of the substance (*in the cold*) into α-naphthafluorane, which, when highly diluted with H_2SO_4, exhibits a brilliant yellow fluorescence and shows $\lambda\lambda$ 496 and 470. As has been shown by Csanyi (Berichte, 1921), this brown substance is *o*–*o*–α-naphtholphthalein,



(I)

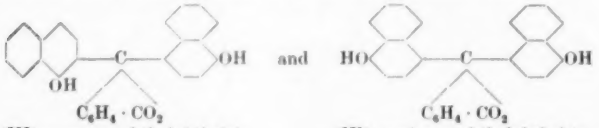
of which α-naphthafluorane



(II)

is the anhydride.

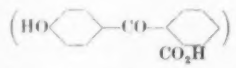
There are two possibilities for the white ingredient, viz. :—



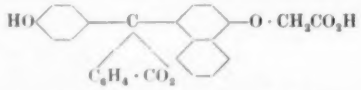
(III) *o–p–α*-naphtholphthalein. (IV) *p–p'–α*-naphtholphthalein.

As only two substances are known, whilst three are possible, some experiments were done to try to clear the subject up. Csanyi had obtained the dimethyl-ether of the genuine *di-para* substance by condensing α-naphthol methyl-ether with phthalic anhydride, but he did not succeed in removing the methyl groups from his ether—so that the properties of the genuine *p–p–α*-naphtholphthalein remain unknown. Similarly, I have tried with α-naphthoxyacetic acid as the starting substance, the group OCH_2CO_2H having a marked para-directive influence.

Realising that my phenol-α-naphtholphthalein (of Part II, 1918) must also be a mixture of *o–p* and *p–p* substances, I combined phenolphthalic acid

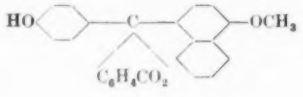


with naphthoxyacetic acid. This gave the substance



This is *colourless* in alkali, but when the alkali is present in traces only it exhibits a brown colour of λ 485. The explanation of this low colour is that the group $C_{10}H_6O \cdot CH_2CO_2H$ is inactive (*i.e.* merely a "load"). The substance is therefore "monocyclic," and has the colour of a "loaded" *p*-oxybenzophenone. Its colour in concentrated sulphuric acid is higher, viz. a blue of λ 592.

Violent treatment with alcoholic sulphuric acid effected a slight hydrolysis, producing a trace of genuine *p–p*-phenol-α-naphtholphthalein, bluish purple in ammonia (λ 601) and violet in concentrated H_2SO_4 (λ 587). Since the mixed phenol-naphtholphthalein of Part II had λ 607 in alkali and λ 566 in sulphuric acid, one can infer that the unknown *o–p*-phenol-α-naphtholphthalein must have λ about 610 to 615 in alkali and about 550 in sulphuric acid. Similarly, using α-naphthol methyl-ether, the monocyclic substance



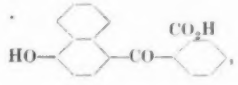
was obtained. This is orange in alkali (λ about 470) and cornflower-blue in concentrated H_2SO_4 (λ 572). It could not be demethylated.

An attempt was made to approach the problem from another angle. Since phenolphthalic acid is easily obtained from phenolphthalein by means of the action of hydroxylamine, I attempted to "split" commercial naphtholphthalein by the same means. The reaction is extremely slow, about 100 times slower than in the standard case, and only a small yield of α-naphtholphthalic acid was obtained. It was purified by extracting the crude product with solution of $NaHCO_3$. The acid is straw coloured and gives a deep yellow in concentrated H_2SO_4, changing to rose colour. This has the absorption-bands $\lambda\lambda$ 417 and 500. The alkali solution of the acid is light yellow, with λ 379 even in very high dilution.

The product from condensing α-naphthol with phthalic anhydride and anhydrous $SnCl_4$ appears to be the same substance, for it has λ 380 in alkali and $\lambda\lambda$ 497, 410, and 338 in concentrated H_2SO_4.

Both specimens, when slightly warmed with α-naphthol and sulphuric acid, give the white naphtholphthalein of λ 650 in alkali.

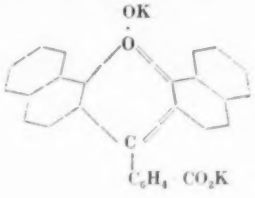
4-Methoxynaphthoylbenzoic acid was also made from α-naphthol methyl-ether and agreed with the description in the literature (Scholl, Seer, and Zinke, 1921). It has $\lambda\lambda$ 525 and 495 in concentrated H_2SO_4 and gives a sparingly soluble ammonium salt. The methyl group could not be removed, so that the substance



from which *p*–*p*–α-naphtholphthalein could have been synthesised, was not obtained in this way either.

Note.—In the monocyclic series the naphthalene benzene colour factor is about 1·13—for example, 4-oxynaphthaldehyde has λ 374, as against λ 330 for 4-oxybenzaldehyde. In the dicyclic series the factor is 1·08.

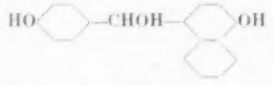
The green colour obtained by warming α-naphthafluorane in alcohol with excess of powdered KOH is not a solution of *o*–*o*–α-naphtholphthalein, since its absorption goes up to λ 720 and is quite diffuse. The colour is also destroyed by water. This green is probably of oxonium-salt origin, viz.—



Similarly, fluorane (carefully purified from phenolphthalein by repeated treatment with alkali) is purplish pink when dissolved in alcoholic potash : λ 573. Since water destroys the colour, it is probably due to an oxonium salt and not to *o–o*-phenolphthalein.

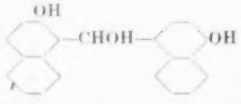
The melting-point of *o–o–α*-naphtholphthalein (the brown, sparingly soluble kind) is 234 (Copisarow and Weizmann give 210, their product being evidently insufficiently purified).

The high colour of *p–p*-phenol-*α*-naphtholphthalein indicates that *p–p*-(di)-*α*-naphtholphthalein should have its band at about λ 650. I infer therefore that the main (white) ingredient of commercial naphtholphthalein is this substance (Formula IV). On the other hand, the calculated λ is much lower, viz. either 602 or 628, according as it is calculated from naphthafluorescein or from a factor derived from the safranines (see Part XVI, p. 234). The value 650 is consistent, however, with dioxybenznaphthhydrol of λ 590 described on the same page, it now being likely that that substance is not 2–4′ but 4–4′ in constitution, *i.e.*—



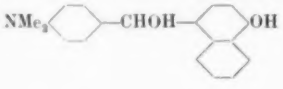
The band of dioxybenznaphthhydrol, viz. 590, is 51 higher than that of 4–4′-dioxybenzhydrol, and the band of *p–p*-phenol-*α*-naphtholphthalein (601) is 47 higher than that of phenolphthalein, all of which facts are corroborative evidence, since 601 plus 47 is nearly 650.

Having been presented by Professor G. T. Morgan with a specimen of 4-oxy-1-naphthaldehyde, I have been enabled to prepare some other substances which throw light on the subject. The substance 2–4′-dioxydinaphthhydrol from betanaphthol

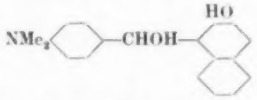


has a vague band near 680 when observed in concentrated H_2SO_4 : it has a green colour in alkali, but this faded so rapidly on keeping that its band could not be observed. The product from alphanaphthol is a mixture of the 2–4′ and 4–4′ dioxydinaphthhydrols, substances which are the *o–p*- and *p–p*-naphtholphthaleins minus the $C_6H_4CO_2H$ group. The former, which is isomeric with the above 2–4′ compound, has λ 648 and the latter λ 635 when observed in alkali (ammonia was used) ; both have λ 640 in H_2SO_4.

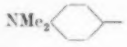
When combined with dimethylaniline the aldehyde gives



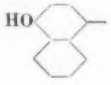
which has λλ 635 and 500. The substance



from dimethylaminobenzaldehyd and β-naphthol has λλ 638 and 575. It is interesting to note that the group



has the same effect as the group



in this field.

The final conclusion is that the white part of naphtholphthalein is mainly the *pp'* variety, but contains some *o–p*, just as commercial phenolphthalein probably contains a proportion of *o–p*-phenolphthalein.

o–p-phenolphthalein (Part III of this series, 1918) has been re-examined. It has not yet been obtained in reasonable quantity on account of the difficulty of preparing a pure specimen of the starting material 2'-oxybenzoyl-2-benzoic acid (Ullmann and Schmidt, 1921). This acid is condensed with phenol and sulphuric acid at 90°. *o–p*-phenolphthalein closely resembles phenolphthalein physically, and has almost the same alkaline colour, viz. λ 552 (phenolphthalein 554).

5'-amino-2'-4-dioxydiphenylphthalide (amino-*o–p*-phenolphthalein of Part III) is purple in alkali, λ 570.

It was described as bottle-green with λ 575 in Part III, owing to an unsuspected admixture of indophenol with the preparation. All attempts to de-aminate this substance (and thus obtain *o–p*-phenolphthalein in quantity) have failed. Failure also attended my efforts to de-brominate 5'-bromo-*o–p*-phenolphthalein, and to de-carboxylate *o–p*-phenolphthalein-5'-carboxylic acid.

Ullmann and Schmidt's 3–4–5–6-tetrachloro-2'-oxybenzoyl-2-benzoic acid is easily purified. From it were made: (1) tetrachloro-*o–p*-phenolphthalein (λ 576); (2) tetrachloro-*o–p*-phenolthymolphthalein (λ 597); (3) tetrachloro-*o–p*-phenolmetacresolphthalein (λ 590); and tetrachloro-*o–p*-phenolalphanaphtholphthalein (λ 630).

Some other benzhydrol colours have been examined:—

(*a*) 3–4–3'-trioxybenzhydrol has a green fluorescence in alkali. The absorption-band is at about λ 720.

(*b*) 3–4–2'-trioxybenzhydrol has λ 700 in NaOH, λ 560 in NH_3, and λ 510 in HCl—without fluorescence.

(*c*) 3–4–4′-trioxybenzhydrol has λ 640 in NaOH, λ 568 in NH_3, and λ 533 in acid—also without fluorescence.

(*d*) The 4′-methyl-ether of the foregoing has λ 480 in alkali.

(*e*) 2′-nitro-3–4-dioxybenzhydrol has λ 430 in NaOH and λ 360 in NH_3.

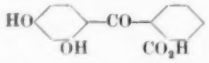
(*f*) 2–4-dioxybenzhydrol has λ 350 broad. 3–4–2′-trioxybenzophenone was also observed. It has λ 450 in alkali. 2–2′–4–4′-tetraoxybenzophenone has λλ 449, 406, and 375. 2–4-dioxybenzophenone has λλ 340 and 420. 2–2′–5–5′-tetraoxybenzophenone has λ 388.

4-oxybenzophenone has λ 353 in alkali and λ 410 in conc. sulphuric acid.

A related substance is the oxyketone 4-oxybenzoylnaphthalene, made by condensing benzoylchloride with α-naphthylbenzoate (using $AlCl_3$), and hydrolysing. It has λ 495 in concentrated H_2SO_4, whereas *p*-oxybenzophenone, as stated, has λ 410. In alkali it is yellow, λ 370 broad.

4-dimethylamino-3′–4′–3″–4″-tetraoxytriphenylcarbinol is multicoloured: green (λ 700) in alkali, violet (λ 595) in bicarbonate, and rose (λ 565) in acid.

Phenolphthalic acid has λ 350 in alkali and resorcinol-phthalic acid



has λ 380. The colour in H_2SO_4 of the latter is lower, λ 428, than that of the former.

B. New Azo-dye Observations. See Table in Part XVII. p. 279.

4-oxy-4′-dimethylamino-azobenzene has λλ 572+532.
4-ethoxy-4′- ,, ,, ,, λ 548 broad.
4-acetamino-4′- ,, ,, ,, λ 540 ,,
4-amino-4′- ,, ,, ,, λλ 562+518+500.

4–4′-benzene-disazo-dimethylaniline has λλ 544+510 (and about 570 faint).

4′-nitrobenzeneazo-2-bromo-1-naphthol has λ 608 in alcoholic alkali.

Benzeneazo-" H-acid " has λ 541 in NaOH, λλ 529+494 in HCl, and λλ 545 and 502 in acetic acid.

Ditolyl-tetrazo-" H-acid " has λ 580 (+λ 540 faint) in all media.

1-oxynaphthyl-3–6-disulphonic-acid-8-azo-phenol has λλ 560+494 in all media.

1-oxynaphthyl-3–6-disulphonic-acid-8-azo-resorcinol has λ 491 in alkali (and 545 in addition in acid).

5-amino-2–4′-dioxyazobenzene has λ 460 in alkali.

2–4′-dioxyazobenzene-5-carboxylic acid has λ 475 in alkali.

4-oxyphenyldiazotate of sodium in NaOH has λλ 460 and 380.

m-methoxy-derivative of methyl-orange is lower in colour than methyl-orange, λλ 510+480.

2-2′-dimethoxy-derivative of methyl-orange has the same absorption as methyl-orange, viz. 537+495. The effects of these two CH_3O groups cancel one another.

4-sulphonaphthalene-azodimethylaniline has two *broad* bands, just above those of methyl-orange.

C. New Hydrazone Observations.

Dimethylaminobenzaldehyde-*p*-nitrophenylhydrazone has λ 460 in acid and λ 540 in alcoholic potash.

m-nitrobenzaldehyde-phenylhydrazone and *p*-nitrobenzophenone-phenylhydrazone are coloured deep olive-black by concentrated alcoholic potash, but weaker potash gives λλ 440 and 480 only, respectively.

p-oxybenzaldehyde-phenylhydrazone gives only λ 345 with potash.

D. Miscellaneous Observations.

β-β-dinaphthoxanthene in H_2SO_4 has λ 430, fluorescent.

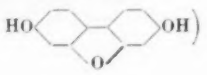
β-β-dinaphthoxanthhydrol in H_2SO_4 has λλ 508+484, fluorescent.

C-methyl-β-β-dinaphthoxanthene in H_2SO_4 has λ 452, fluorescent.

C-phenyl-β-β-dinaphthoxanthhydrol in H_2SO_4 has λλ 495+470, both of which are 5 less than those of α-naphthafluorane. The substance is the anhydride of α-naphtholbenzeine, which has λ 705 in alkali (*c.f.* Part XIX).

3-(or ortho)-oxyfluoresceine, made from oxyquinol and resorcinol-phthalic acid, has λλ 523 and 498.

" Resorcin-ether " (which is probably



has λ 486.

Quinone-2-carboxylic acid, from gentisic acid, has λλ 525 and 463 in bicarbonate and λ 455 in acid. Its quinhydrone has λλ 720+580+510.

Phenolphthaleinoxime has λλ 410 and 370 in alkali.

Neutral violurate ion has a broad band, λ 555 ±35. When alkaline, the colour is lower, λ 515 ±40; dimethyl- and diphenylviolurates and phenylisoxazolonoxime are all very similar in colour, λ 555 broad; murexide, which may be considered as alloxan-uramil azomethine or as the anhydride of dibarbiturylhydroxylamine, has the same absorption as alkaline violurate.

3-4-dioxyphthalic acid has λ 400 in ammonia, fluorescent: the 3-6-compound, which is even more fluorescent, is given in Part XVI, p. 236. 2-5-dioxyterephthalic acid has λ 355 in alkali, non-fluorescent: its diethyl ester

has λ 404 in alkali, with an orange fluorescence, but when neutral has λ 362 only, with blue fluorescence; both the acid and its ester have λ 399 in strong sulphuric acid. The related substance paradiketohexamethylene has λ 333 in alkali, λ 385 in strong sulphuric acid, and λ 358 free (fluorescent).

Similarly, succinosuccinic ester has λ 350 when free (blue fluorescence); its sodium compound has λ 388; its H_2SO_4 solution λ 400: succinosuccinic acid has λ 365; its alkaline solution λ 385; and its H_2SO_4 solution λ 391. The decided colours of these hydrogenated benzene derivatives are very interesting.

4-nitrophthalic acid gives two isomeric phthaleins with phenol. Phenol-4-nitrophthalein has λ 542, twelve units lower than that of ordinary phenolphthalein (para-derivatives *are* generally lowest, as shown in Parts XI and XV of this work). Phenol-5-nitrophthalein has λ 570 (same as the 3-nitro), yet phenol-3–5-dinitrophthalein appears to have its band at λ 582 only, 7 less than expected.

Phenol-metaxylenolphthalein has λ 573; phenolparaxylenolphthalein λ 575; bis-paraxylenolphthalein λ 590; bis-paraxylenol-tetrachlorophthalein λ 625; phenol-4-oxyorthoxylenephthalein (4–5-dimethyl-derivative of *o–p*-phenolphthalein) λ 573; and the 2-iodo-3-methyl-derivative of phenolphthalein has λ 576.

E. Sulphur Compounds.

p–p-dioxydiphenylsulphide gives with excess of $FeCl_3$ a quinone-like body, λ 410. This is probably $SO(C_6H_4OH)_2$. With less oxidant, a quinhydrone analogous to benzoquinhydrone is obtained: black powder, soluble to dull green in concentrated sulphuric acid, with $\lambda\lambda$ 750 and 500. Similarly, thioaniline (diaminodi-phenylsulphide) gives an indigo-coloured quinhydrone: $\lambda\lambda$ in H_2SO_4 about 755+515.

The very interesting substance thianthrene-quinhydrone, which results from heating a solution of colourless thianthrene in concentrated H_2SO_4, is purple, with λ 545; the solution becomes blue on slight dilution, and then has two more bands, $\lambda\lambda$ 700 and 490 (compare anthracene, Part XIX).

Diaminothianthrene is yellow even in very high dilution, λ 342: its salts are colourless and non-fluorescent, λ 310. When oxidised they give a blue-black quinhydrone, deep blue in concentrated H_2SO_4.

SOME ADDITIONS TO THE KNOWLEDGE OF *PROCOLOPHON*, *LYSTROSAURUS*, *NOTEOSUCHUS*, AND *CISTECEPHALUS*.

By F. von Huene, Tübingen.

(Communicated by Dr. S. H. Haughton.)

(With seven Figures.)

During my stay in South Africa in 1924 I appreciated very much the opportunity of making a few studies in the collections of the Albany Museum at Grahamstown and the Transvaal Museum at Pretoria. I am much indebted to Messrs. Hewitt and Swierstra and to Dr. Haughton for their permission and help.

1. *Procolophon trigoniceps*.—Among a great amount of material of this form in the Albany Museum, from Fernrocks (Middelburg District), there is a specimen showing an impression of the posterior part of the roof of

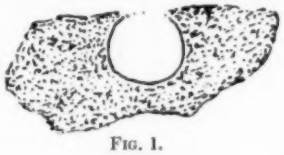


Fig. 1.

the skull with the big foramen parietale and a minutely sculptured surface round it (fig. 1). In no other specimen is this finely grooved sculpture seen. The surface of the bones of the skull is always quite smooth, even round the foramen parietale. Therefore, I am compelled to take this surface for the skin ornamentation. It must have been a thick leathery skin, showing very small polygonal grooves with thick meandering walls between them, somewhat like the surface of the skulls of some stegocephalians, only very much smaller. The interesting fact is that—if this is really skin—it does not cover the foramen parietale, which has a diameter of 12 mm. This would give evidence that in the foramen parietale of *Procolophon* there was still a functioning organ. Not even the border-zone of the large foramen was covered with the skin.

The breadth of the preserved surface is 45 mm. and the length 17 mm. If it were an impression of bone and not skin the sutures should be clearly visible ; but there are none, not even in the middle line.

2. *Lystrosaurus.*—E. C. N. van Hoepen has (Ann. Transvaal Mus., iv, 1, 1913) given an excellent and very detailed account of the osteology of the *Lystrosaurus* skull. There are needed only a few points to complete it, especially the fact that there is a transverse bone in existence. I have observed it in many of the skulls of the Pretoria collection. It will be enough here to mention four specimens—*Lystrosaurus latirostris*, described and figured by van Hoepen in 1913, and the skulls numbered 112, 21, 4000—and to figure two of them.

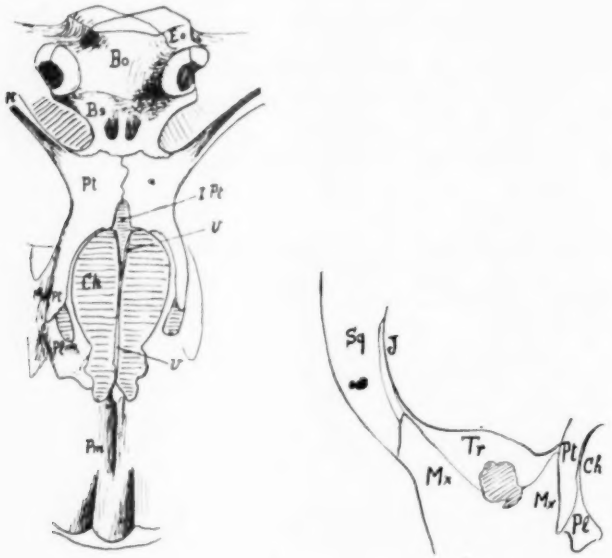


FIG. 2.

The transverse bone is not visible in the full palatal view of the skull, but more in half lateral view, because it lies in the angle between the jugal and pterygoid at the side and not in the plane of the palate. Where the transverse bone and maxilla are touching each other the bony wall is very thin, and in the first-mentioned specimen it is broken off, looking like a circular opening. Dr. van Hoepen had taken it for part of the jugal. The transverse bone in *Lystrosaurus* occupies the same position as in *Dicynodon* (Pal. Zeitschr., v, 1, 1922, pp. 58–71).

I could also trace the palatine quite clearly. It is a small bone. Most of it is situated in front of the anterior extremity of the pterygoid, between the latter, the maxilla, and the premaxilla. But it still has a long and

narrow posterior wing following the medial border of the pterygoid, so that this bone does not touch the choanae except on a very short line at their posterior end.

The pterygoids have an interpterygoid space between them, which

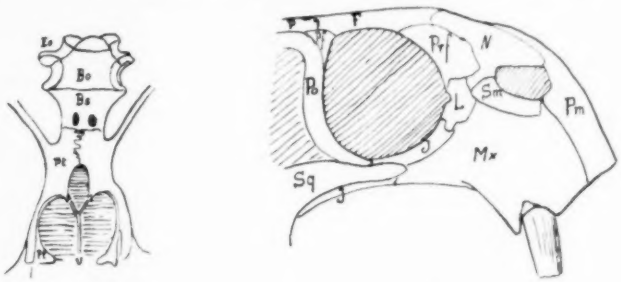


Fig. 3.

lies behind the choanae. In the anterior half this interpterygoidal space is closed and bordered by the vomer. The vomer in the palatine plane appears as an extremely thin lamella standing vertical in the middle line. Posteriorly it is divided into two diverging lamellae. These come in touch

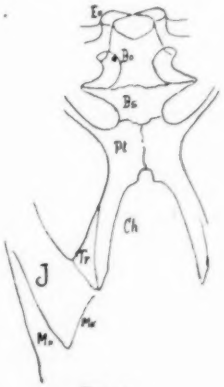


Fig. 4.

with the corners of the pterygoids. Especially in specimen No. 112, they are evidently denticulated with these protruded corners of the pterygoids.

It might be mentioned—but this is not a new observation—that in lateral view the jugal appears at two places because the anterior extremity of the squamosal covers it at the surface. So the jugal is visible at the

lower border of the orbit, and again below the squamosal and in continuation of the posterior extremity of the maxilla.

I give figures of two dorsal vertebrae. *Lystrosaurus* vertebrae have never been described in detail. They are deeply amphicoelous. The rib articulation is very broad so that the capitulum costae still is touching the intervertebral space, with the tuberculum high up at the moderately long diapophysis.

a *b*

FIG. 5.

a *b*

FIG. 6.

3. *Noteosuchus colletti* (Watson). This specimen has never been fully described and figured.* It comes from the *Cistecephalus* zone of Grass Ridge, Cradock District, and is now in the Albany Museum. I cannot give a complete description of it, as I only studied a few points in the very short time I could spend at Grahamstown ; I had first made a sketch of it from a plaster cast in the South African Museum at Cape Town.

Skull, neck, shoulder girdle, with most of the front legs are missing. The ten posterior dorsal vertebrae, the two sacrals, and most of the caudal vertebrae are preserved in articulation. The posterior dorsals exhibit small intercentra. The dorsal spines in the dorsals are broad and of medium height. The height of their centra is about half of the length. Many abdominal ribs are lying between the dorsal ribs. The anterior tail vertebrae have long, straight transverse processes.

* Since this account was written, a description of *Noteosuchus* by Broom has appeared in Rec. Albany Mus., iii, 1925, pp. 300–305.

The pelvis has a closed acetabulum. The ilium possesses mainly a spina posterior. Ischium and pubis are plate-like, broad and short as shown in the figure, but not quite complete.

Fig. 7.

The femur is curved like an S and of the same length as the simply curved tibia and the thin fibula. The calcaneum seems to possess a process. The metatarsals increase in size from the 1st to the 4th ; the 5th is short, stout, and hooked ; its first phalanx has nearly the length of the metatarsal ; the second is likely to be large too. The 4th metatarsal is the most powerful.

4. ? Young *Cistecephalus*.—On the same plate of stone as *Noteosuchus colletti* there is a very tiny crushed skeleton. It is preserved from the skull to the pelvis. The length of this part is 56 mm. The skull has a length of 14 mm., and from humerus to pelvis is 37 mm. The skull has only a single temporal opening; therefore it cannot be a young *Noteosuchus*, which is supposed to have possessed two. The orbit is large and situated very high up on the skull. The small nasal openings are at the top of the snout. The premaxilla reminds one of *Howesia*. The squamosal has the same shape as in Dicynodonts, and so is of a very characteristic form. The parietal is broad and the frontal narrow, the maxilla short. All of this gives the skull a shape like that of *Cistecephalus*. It cannot be a Thecodont like *Noteosuchus* on account of the single temporal opening and of the typical shape of the squamosal. Femur and humerus are strong and stout and also of dicynodont shape. The *Howesia*-like premaxilla may be a character of very young dicynodont animals, and the same a few very small teeth which are supposed to disappear in the adult life. If the determination be right, it would be the very first known quite juvenile dicynodont reptile exhibiting a more primitive kind of feeding than adult animals.

EXPLANATION OF FIGURES.

Fig. 1. *Procolophon trigoniceps* from Fernrocks, Middelburg District. Probable impression of skin round the foramen parietale. Natural size. Specimen in the Albany Museum, Grahamstown.

Fig. 2. *Lystrosaurus latirostris*. Specimen from Harrismith, figured in 1913 by Dr. van Hoepen, in the Transvaal Museum, Pretoria. Half natural size. *a*, palatal view; *b*, slightly oblique ventral aspect. Explanation of letters for this and the following figures: Bo, basioccipital; Ch, Choanae; F, frontal; J, jugal; I. Pt, interpterygoidal space; L, lachrymal; Mx, maxilla; N, nasal; P, parietal; Pf, postfrontal; Pl, palatine; Pm, premaxilla; Po, postorbital; Prf, prefrontal; Pt, pterygoid; Sm, septomaxilla; Sq, squamosal; Tr, transversum; V, vomer.

Fig. 3. *Lystrosaurus* sp. from Harrismith. Specimen in the Transvaal Museum, No. 112. Half natural size. *a*, palatal aspect, showing the relations of vomer with pterygoid and palatine; *b*, right lateral aspect.

Fig. 4. *Lystrosaurus* sp. from Harrismith, in the Transvaal Museum, No. 21. Half natural size. Palatal aspect.

Fig. 5. *Lystrosaurus* sp. from Harrismith, in the Transvaal Museum, No. 163. Anterior dorsal vertebra. Half natural size. *a*, from left side, *b*, longitudinal section of centrum.

Fig. 6. *Lystrosaurus* sp. from Harrismith, in the Transvaal Museum, No. 109. *a*, from left side; *b*, from above.

Fig. 7. *Noteosuchus colletti* from *Cistecephalus* zone of Grass Ridge, Cradock District. In the Albany Museum. Half natural size. Mainly from plaster cast in the South African Museum, Cape Town, but left half of pelvis, left front leg, and fifth toe of right hind leg drawn from the type. The ten posterior dorsal vertebrae and the two sacrals are exposed in the divide of the two plates of matrix in the middle line. Ventral aspect of specimen.

NEW AND NOTEWORTHY SOUTH AFRICAN CHAROPHYTA.

I.

By James Groves and Edith L. Stephens.

(With Plates XII–XV.)

Alexander Braun, in his admirable work on the African Charophyta ("Die Characeen Afrika's," in Monatsb. d. Königl. Akad. Wiss. for 1867, Berlin, 1868, pp. 782–800, 873–944, in reprint pp. 782–872), dealt exhaustively with practically all the material which had been collected in South Africa up to the date of its publication. Since that date, particularly within the last thirty years, fresh districts have been explored for these plants, especially in the extreme south of the continent. The following notes relate to some of the more important discoveries which have resulted.

South Africa is rich in endemic types belonging to the group. Some characters which, in other parts of the world, serve to separate large sections are here found to break down—notably that of the dactyl in *Nitella* consisting of a single cell, or of more than one cell. This character is usually employed to mark off two of the primary divisions of the genus, and in other continents is apparently constant. In South Africa there are species which produce some single-celled dactyls, others composed of two cells, some individuals having all or nearly all 1-celled, others all or nearly all 2-celled, others again having many of each type. To meet the case Braun suggested (*loc. cit.*, p. 879) the formation of a separate section *Heterodactylae*, but did not carry this suggestion into effect, either in the systematic table at the beginning of the work itself, or in the Fragmente Monogr. Charac. (1882), *N. tricuspis* (=*N. Dregeana*) being placed in both works under his section *Monarthrodactylae*. It seems to us desirable, as a matter of convenience at any rate, to maintain the section *Heterodactylae*, especially as the species which come under it show a marked affinity to some of those having the dactyls uniformly 2-celled. With the diplostephanous Charas again no satisfactory line can be drawn, among the South African species, between those with a diplostichous and those with a triplostichous cortex.

We hope within the next few years to publish a full account of all

species known to occur in Africa, south of the Equator, and for the purposes of that work are arranging records under the following districts, founded on political boundaries which, for the time being at least, seems the most convenient plan. This arrangement is adopted in the present notes.

I. Union of South Africa.
  (i.) Cape.*
  (ii.) Natal and Zululand.
  (iii.) Orange Free State and Basutoland.
  (iv.) Transvaal and Swaziland.
II. Bechuanaland Protectorate.
III. South-West Africa.†
IV. Southern Rhodesia.
V. Northern Rhodesia.
VI. Nyassaland Protectorate.
VII. Portuguese East Africa.
VIII. Tanganyika Territory, with Zanzibar, Pemba, and Mafia Islands.
IX. Kenya Colony and Protectorate.
X. Uganda Protectorate.
XI. Congo.
XII. French Equatorial Africa.
XIII. Angola.
XIV. St. Helena, Ascension, and other islands on the west.
XV. Mascarene Islands (Madagascar, Mauritius, Bourbon, Seychelles and islets, including Comoro Islands).

To arrive at the dimensions of the fruits and other parts, for the descriptions of the new species, a number of measurements have been made: there is, however, so much variation in this respect, even in individual plants from the same gathering, that it may well happen that examples will be found exceeding or falling short of our measurements, which should therefore be regarded as roughly approximating to the average.

For the information of non-South African readers it may be explained that "vlei" is a general term in South Africa for a body of water larger than a pool (or for a marshy piece of ground). Vleis vary in size from ponds to lakes, and may be permanent or may contain water only during part of the year. The latter (temporary vleis) are much more frequent, and as a rule

* For convenience, we are using throughout this familiar contraction for the "Province of the Cape of Good Hope"; this is coterminous with the boundaries of the old Cape Colony, and includes British Bechuanaland, but not the Bechuanaland Protectorate.

† Formerly "German South-West Africa," now a mandate to the Union of South Africa. Includes Great Namaqualand, Damaraland, and Amboland (Ovamboland).

richer in plant- and animal-life than the permanent sheets of water. In the Transvaal and Rhodesia the term " pan " is more often used, with the same meaning as " vlei."

When specimens bear distinctive numbers these are quoted after the collector's name. The numbers enclosed in square brackets are those of the Cryptogamic Herbarium at Pretoria. Those following a collector's name, but preceded by the initials E. L. S., have been given in the second author's Charophyte Herbarium to unnumbered material received from other collectors.

We shall be glad to receive specimens of any Charophytes, especially from the more remote districts, from which little material has yet been obtained, and the second author will be pleased to supply materials and instructions for collecting, and arrange for the postage of specimens. (Address to the Botanical Department, University of Cape Town.) When practicable it is desirable to preserve some selected pieces in formalin (about 2 per cent. solution) in addition to drying herbarium specimens, but, if it is not convenient to do both, we prefer to have them in formalin. It is important, when possible, to secure good fruiting examples, and with dioecious species to collect both sexes. The male plants of dioecious species, owing to their extra large antheridia, are very conspicuous, and the more modest female plants are apt to be overlooked. Bulbils of distinctive character are often to be found on the rooting portions, and with a little care these can be secured when the plants occur in shallow water.

Our thanks are due to the many friends and correspondents who have forwarded us specimens, and to Mr. and Mrs. E. J. Steer of Sea Point, Cape Town, and Mrs. F. Pattison of Redhouse, Port Elizabeth, for much assistance to the second author in the work of collecting. This has been further facilitated by a grant from the Research Grant Board of the Union of South Africa towards the collecting materials used in these investigations. We are much indebted to Miss Mary Groves for her drawings of the new species, which have been admirably reproduced by Messrs. Charles Whittingham & Griggs.

Nitella acuminata, Braun, in Hooker's Journ. Bot., vol. i, p. 292 (as var. *Bellangeri*), 1849.

IV. Southern Rhodesia. Renardia, Gadyeura, Feb. 1924, Emilia F. Noel.

The first record, we believe, of the occurrence of this species on the mainland of Africa, south of the Equator. It has long been known from the Mascarene Islands, and is recorded by Braun (Fragm. Monogr. Charac., p. 357) from one locality in North Africa, Seriba Ghattas (Egyptian Sudan).

N. acuminata is readily distinguishable from all other South African Nitellas by having uniformly one-celled dactyls, with very long acuminate points.

N. praeclara, sp. nov. (Plate XII.)

Homoeoclema heterodactyla (dactylis partim uni- partim bi-cellulati), dioecia. Species insignis. Caulis et ramuli valde tumidi, cellulis nonnullis interdum fere globosis. Oogonia verticillata pedicellata e ramulorum nodo primario solum plerumque emanentes. Antheridia saepe pedicellata e ramulorum nodo primario et verticilli fundo emanentes.

Dioecious. Stem very stout, → 2 mm. in diameter, the lowest segment usually much elongated, much branched above. Sterile whorls of stem and main branches usually distant; branchlets usually 5, each consisting of a single large tumid allantoid incurved, or nearly spherical cell, or of two large tumid cells (the upper usually nearly spherical) with an intervening node. Fertile branches short, the internodes being much abbreviated, forming small densely crowded heads usually much shorter than the main sterile whorls which enclose them. Fertile branchlets of ♀ plant usually 5–6, each consisting of a cylindrical cell (the primary ray) with a node at its distal end bearing a whorl of 3–5 oogonia, with sometimes 1–2 lateral rays taking the place of some of the oogonia, and a central cylindrical or tumid cell giving rise at its distal end to a whorl of usually 4 often tumid cells each surmounted by usually 1–3 minute dactyls. Fertile branchlets of ♂ plant usually 6, usually three times forked, with 3–4 (occasionally 5) rays at each furcation, the dactyls larger than in the ♀ plant. Dactyls, some 1- some 2-celled, the single or upper cell, as the case may be, narrowly conical acute, the lower, when present, tapering upwards, or sometimes tumid. Oogonia distinctly stalked, produced in clusters at the first branchlet-node only, c. 400–425 μ long, 315–350 μ broad, showing about 9 convolutions; coronula c. 45–60 μ broad, 20–30 μ high, the cells of irregular size, persistent.

Oospores round or roundish-ovoid, c. 275–300 μ long, 250–275 μ broad, 150–175 μ thick, dark warm brown, showing about 8 well-marked ridges terminating in a slight crest; membrane thick, the surface coarsely reticulate, with about 5–6 meshes across the space between the ridges.

Antheridia at the first branchlet-node and at the base of the whorl often shortly stalked, → c. 600 μ in diameter.

I. i. Cape. Valkenberg Vlei, near Cape Town, Nov. 1907, E. P. Phillips, 130, 131; from the same locality 1912–1924 (July–Oct.), E. L. S. 2, 3, 5, 6, 33, 35; vleis and pools near big dune on Lansdowne Road, Cape Flats, near Cape Town, Oct. 1921, E. L. S. 44. Caledon, shallow pool beside Swellendam Road, Oct. 1921, E. L. S. 46.

An extremely beautiful and remarkably distinct-looking species. In the living state its stoutness, transparency, and turgidity give it the appearance of pale green blown Venetian glass, an effect enhanced by its very upright and peculiarly rigid habit. It bears some superficial resemblance to the South American and West Indian *N. cernua*. In the whorled oogonia and remarkably tumid almost spherical cells it resembles the South Australian *N. tumida*. It attains a height of 20 cm., but is usually about 12 cm. Despite its unlikeness in appearance, it is nearly allied to *N. Dregeana*, the other dioecious member of the *Heterodactylae*, differing in the remarkably thick tumid cells of the stem and branchlets, the minute dactyls, the rounded fruiting heads, the often completely whorled groups of stalked oogonia, etc.

It occurs only in shallow temporary pools and vleis formed during the rainy season. When the underlying soil is calcareous, the older portions become annularly incrusted.

N. divaricata, sp. nov. (Plate XIII, figs. 11–19.)

Homoeoclema heterodactyla (*gymnocephala ?*) *monoecia. Verticilli steriles laxi, fertiles in capitulis non congestis. Ramuli verticillorum sterilium plerumque* 6 ; *vulgo bis-furcatis, fertilium pq.* 8, *bis-vel ter-furcatis, radiis inaequalibus et conspicue divergentibus, ad nodos primarios pq.* 5, *secundarios et tertiarios pq.* 3–4. *Dactyli abbreviati, partim uni-, partim bi-cellulati, cellula ultima conica acuta. Gametangia e ramulorum nodibus primariis et* (*quum terfurcati*) *secundariis emanentes, nodo ultimo sterile.*

Monoecious. Stem rather slender, diameter c. 400 μ. Sterile whorls usually of 6 branchlets ; branchlets usually twice furcate, the primary ray exceeding half the length of the entire branchlet, producing at the first node 3–5 rays, at the second 2–3, the tertiary rays much shorter than the secondary. Fertile whorls of usually 8 branchlets, twice or thrice furcate, the rays conspicuously divergent and unequal in length, producing at the first node usually 5 rays, at the second and third 3–4, the ultimate node sterile ; dactyls in some cases all bicellulate, in some partly uni-, partly bi-cellulate, occasionally all unicellulate, almost all short, tapering gradually from the base, the upper cell, when present, slender, conical, acute. Gametangia produced often together at the first, and when thrice furcate at the second node. Oogonia solitary or geminate broadly ellipsoid, c. 425–500 μ long (excl. cor.), 350–400 μ broad ; spiral cells showing 9–10 convolutions ; coronula c. 50 μ broad, 35 μ high. Oospores very dark brown, broadly ellipsoid to almost round, c. 275–300 μ long (excl. crest), 250–300 μ broad, 175–200 μ thick, showing about 8 thin high ridges terminating in a conspicuously tall crest ; membrane dark warm brown, thick, brittle, with fairly regular reticulate decoration, about 9 meshes between the spiral ridges. Antheridia rather broad and usually somewhat flattened at the top, c. 250–280 μ long, 300–350 μ broad.

I. iv. Transvaal. In pan, Belfast, Nov. 1909, E. M. Doidge [1135B].

Dr. Doidge's specimens preserved in spirit show a slender plant about 35 cm. high of rather lax habit and long internodes, the sterile branchlets about 30 mm. long, the fertile whorls not forming condensed heads and having the rays divaricate. It may prove to be slightly gloeocephalous when plants in a younger state are available. In the sterile ultimate nodes of the branchlets and the abbreviated dactyls *N. divaricata* shows an affinity to the brachydactylous section of the Arthrodactylae. It resembles the North African *N. abyssinica* Braun in its short dactyls, partly 1- partly 2-celled, but apparently differs in the marked divergence of the rays, the less furcate branchlets, the fair-sized fruits, and the larger antheridia. Braun gives the diameter of the antheridia of *N. abyssinica* as 0·20–0·22 mm., and describes the oogonia as very small, but gives no measurements. He refers to the dactyls as "bicellularibus (rarius unicellularibus et tunc brevissimis)," whereas in the present species unicellular dactyls are frequent and often fairly long. Nordstedt had not seen ripe fruit of *N. abyssinica*, so was unable to describe the membrane. We have not seen specimens of either of the original Abyssinian plants on which that species was founded. The plant from Seriba Ghattas (Schweinfurth 2574) is a very doubtful one.

Since our illustration was produced, Canon Bullock-Webster, who has given particular attention to oospore-membranes, has favoured us with a beautiful drawing of the membrane of this species on a much larger scale, showing that each angle of the reticulations terminates in a projecting rounded tubercle.

N. Doidgeae, sp. nov. (Plate XIII, figs. 1–10.)

Homoeoclema arthrodactyla (*normaliter bicellulata*) *flabellata gloeocephala dioecia. Verticilli steriles laxi; fertiles in capitulis congesti et nube mucosa circumdati. Ramuli verticillorum normaliter* 6, *bis- vel raro ter-furcati. Radii secundarii* 4–5, *tertiarii et quaternarii* 2–3. *Dactyli bi- vel raro tricellulati. Gametangia e ramulorum nodibus primariis et secundariis emanentes; oogonia saepe geminata.*

Of medium stature (about 50 cm. high). Stem → c. 400 μ thick, lower internodes more than twice as long as the branchlets. Sterile whorls lax → about 4 cm. in diameter, the branchlets and rays spreading, the primary ray about half the length of the branchlet. Fertile whorls for the most part forming more or less dense heads, the female rather more lax than the male, enveloped in a thick mucous cloud. Branchlets and rays often very unequal in length. Dactyls normally 2- but occasionally 3-celled, the lower cell long and cylindrical, rounded-truncate at its distal extremity, about twice to thrice as broad as the base of the ultimate cell;

ultimate cell normally narrowly conical (75–125 μ long), but in a few instances cylindrical-acuminate (see fig. 5). Oogonia solitary, geminate, or very rarely 3 together, about 400–450 μ long, 350–375 μ broad; spiral cells showing 8–9 convolutions; coronula c. 30 μ high, 65 μ broad. Oospores very broadly ellipsoid-flattened, c. 275–300 μ long, 250 μ broad, 175 μ thick, cold medium brown, showing 7–8 strong but low ridges with no appreciable crest; membrane thin, coarsely and irregularly reticulate. Antheridia, c. 450 μ long, 500 μ broad, produced at first and second nodes.

I. iv. Transvaal. In pan, Belfast, Nov. 1909 and Jan. 1924, E. M. Doidge [1135c]; vlei near Forestry Station, Belfast, Jan. 1924, E. M. Doidge and A. M. Bottomley [1139B]; near Johannesburg, Aug. 1923, M. A. Pocock (E. L. S. 176, part); near Pretoria, March 1924, H. Schweicherdt [1152–3]. To this species also probably belongs a ♀ plant with immature fruit collected at Waterkloof, Pretoria, April 1922, by I. C. Verdoorn (E. L. S. 113).

A very well-marked plant and the only dioecious member of the section at present recorded from South Africa. Of this species also Canon Bullock-Webster has favoured us with a large scale drawing of the oospore membrane showing that the angles of the reticulations have acute projections.

N. hyalina, Agardh, Syst. Alg., p. 126 (1824), *ex parte.*

I. i. Cape. Somerset West, lake at Dynamite Factory, Feb. 1920, E. L. S. 31–32; Port Elizabeth, in Baakens River, 26th Aug. 1912, Florence Pattison (E. L. S. 21, 25); Buffalo River, opposite Orange Grove, and Nahoon River, 1908, G. Rattray; Barkly West, Vaal River at Riverton, 17th Nov. 1919, Helen Tapscott 162; and Donderboschfontein, in clear still water, 30th Sept. 1922, M. Wilman 1830; Armoed's Vlakte, Vryburg, at 3960 ft., Sept. 1921, A. O. D. Mogg [8868A] (4) (5).

IV. Southern Rhodesia. Matoppo Hills, 1905, Lilian S. Gibbs; Salisbury, in stagnant pool, in schist clay, at 4800 ft., Aug. 1921, F. Eyles 3181, and Nov. 1923, F. Eyles 3840.

The record of this species for South Africa has hitherto depended on Braun's determination of a plant collected by Zeyher in Dec. 1847 "im Kanal des Zwartkopsrivier, Dist. Uitenhage" (No. 4647). Concerning this plant he remarks (Die Characeen Afrika's, p. 819 [891], "Die Cap'schen Exemplare sind im Gegentheil ungewöhnlich locker, die unteren Quirle sehr entfernt und viel langblättriger als die oberen, die Zwischen-blätter in geringer Zahl, zuweilen in ganzen Quirl nur 1–2. Ich habe diese Form früher als var. *oligactis* bezeichnet, aber bei Untersuchung kräftiger entwickelter Exemplare mich überzeugt, dass sie kaum als eigene Abart unterschieden zu werden verdient." Zeyher's plant appears to us a very doubtful one, the few smaller branchlets being apparently merely adventitious, produced *between* the larger ones, and not forming separate series *below* (and usually also *above*) the normal branchlets as in typical *N. hyalina.* The plants we now record correspond

with the typical plant. *N. hyalina* is apparently the most widely distributed of all the Nitellas, occurring in most parts of the world.

N. plumosa, Braun, in Monatsb. Akad. Wiss. Berlin for 1867 (Die Characeen Afrika's), p. 891 (1868).

I. i. Cape. Cape Flats, near Wetton Road Station, Oct. 1921, E. L. S. 45. Cape Peninsula, in stream at Hout Bay, Nov. 1922, E. L. S. 116, also in Lange Vlei, Sept. 1922, and Schoonster's River, Aug. 1924. Caledon, ponds beside Swellendam Road, Oct. 1921, E. L. S. 47.

This extremely beautiful and distinct species had not apparently been collected since its original discovery by Drège, more than eighty years ago, "bei Klein Drakenstein zwischen dem Bergrivier und den Drakensteenbergen," and it is satisfactory to have well-grown examples of both sexes, enabling us to make a fuller examination of the plant. This has elicited the fact that *N. plumosa* belongs to the *Heteroclemae*, having smaller (secondary) branchlets in separate series above and below the primary whorl.

Tolypella glomerata, Leonhardi, in Lotos, vol. xiii, p. 57 (1863).

I. i. Cape Colony. Cape Flats, near Cape Town, vlei near big dune beside Lansdowne Road, Oct. 1921, E. L. S. 40; pool beside Klipfontein Road, Oct. 1921, E. L. S. 52; about 12 miles south of Triangle Station, Worcester, Oct. 1922, E. L. S. 93; pool in bed of stream crossing Barrydale Road near Montagu, Oct. 1923, E. L. S. 125; Riversdale commonage, Aug. 1923, Dr. J. Muir (E. L. S. 143).

These, we believe, represent the first records of any species of *Tolypella* for South Africa. The specimens from the different gatherings exhibit a considerable range of variation, but we have not so far been able to find sufficiently marked characters to separate any of them as distinct species. The shape and colour of the oospore and the breadth and prominence of the ridges thereon are especially variable in the South African plants. In No. 40, the most extreme plant, the oospore is very little longer than broad, dark warm brown to almost purple, with thick broadly flanged ridges, in strong contrast to that of the ordinary European plant, which is ellipsoid, dull yellow to dark cold brown, with low inconspicuous ridges.

Lamprothamnium papulosum, J. Groves, in Journ. Bot., vol. liv, p. 337 (1916); *Chara papulosa* Wallr. (1833); *C. alopecuroidea* Braun (1849); *Lamprothamnus alopecuroides* Braun (1882).

I. i. Cape. Port Elizabeth, in shallow brackish water in estuary of Chatty River at Redhouse, Oct. 1923, Lilian Britten 4070; from the same locality, Feb. 1924, E. L. S. 154*b*; Orange River at Upington, Oct. 1923, Elfrida Krapohl (E. L. S. 127).

The previous record for South Africa for this beautiful species rested upon plants which had been grown at Manchester from fruits contained in mud sent to England

from the neighbourhood of Port Elizabeth, and which provided the material for an excellent paper by Miss Mary M'Nicol on the bulbils and pro-embryo, in Ann. of Bot., vol. xxi, pp. 61–70, t. 8 (1907). The Upington record is notable in that the plant occurred in fresh river water nearly 300 miles inland, whereas in previous localities from which the species has been recorded the water has usually been brackish, and they have usually been quite near the sea coast. It has been found in Northern and Western Europe and in North Africa (Algiers). The generic name *Lamprothamnus*, under which it appears in Braun and Nordstedt's 'Fragmente' and other works, is not available, having been previously given to a genus of *Rubiaceae*. It is to be regretted that the law of priority precludes the adoption of the admirably descriptive specific name *alopecuroides*, see Journ. Bot., 1916, p. 336.

Chara macropogon, Braun, in Linnaea, vol. xvii, p. 116 (1843); *Lychnothamnus macropogon*, Braun (1868); *Macropogon australicum*, Migula (1891).

I. i. Cape. George: Touw River Lagoon, Wilderness, Jan. 1924, E. L. S. 144, and Lang Vlei, The Lakes, Jan. 1924, E. L. S. 147; Port Elizabeth, in brackish water in estuary of Chatty River at Redhouse, Jan. 1924, E. L. S. 154.

As in the case of the foregoing, the previous record for South Africa rested on cultivated specimens raised from mud from the neighbourhood of Port Elizabeth, in this instance in the Department of Botany of the British Museum, see Journ. Bot., 1919, p. 336; 1925, p 183.

This species was first described by Braun under the genus *Chara*, but was subsequently placed by him in the later-formed genus *Lychnothamnus*. In *C. macropogon* the oogonia are usually situated at the base of the whorl in the axils of the branchlets, and the antheridia at the free nodes of the latter, and when occasionally the oogonia also occur at the free nodes it is scarcely ever in company with the antheridia. As stated in a paper on *Lychnothamnus* by J. G. (Journ. Bot., vol. lvii, p. 128, 1919), in two cases in which the oogonia and antheridia had been found together at the same branchlet-node, they did not proceed from different peripheral cells as in the genus *Lychnothamnus*. Another instance has now been noticed (in E. L. S. 154), and the specimen being preserved in fluid, the relative position of the gametangia could be determined with certainty, whereas in the dried specimens referred to in the paper there was an element of doubt. The oogonium in the present instance is clearly seen to originate from the same cell and above the antheridium, the normal position in the genus *Chara*, in which genus therefore we think there can be no doubt it should be reinstated. *C. macropogon* occurs in several parts of Australia and in Tasmania, and a plant collected in China (Hong Kong) has also been referred here. The South African plant is a large lax form, with the stipulodes less strongly developed.

C. corallina, Willdenow in Mém. Acad. Roy. Berlin for 1803 (1805), p. 89, t. 2, fig. 2. (Plate XIV.)

XV. Mascarene Islands. Mauritius, in a comparatively deep part of the Rivière Profonde, above Hesketh Bell Bridge, between Reduit and Moka, 1923–4, E. F. Shepherd.

An important extension of the known range of this curious species, hitherto only reported from India, Burma, Ceylon, Sumatra, and the Philippine Islands, all north of the Equator.

C. corallina differs from the other species of the genus in that the oogonium when occurring at a free branchlet-node is not usually placed directly above the antheridium, the normal position in a monoecious *Chara*, but in a diagonal position in relation to the node, and has the appearance of growing side by side with the antheridium, as in the genus *Lychnothamnus*. Upon closer examination it is seen, however, that the ♀ and ♂ gametangia both proceed from the same peripheral cell of the branchlet-node, instead of from different cells as in *Lychnothamnus*. The one bracteole is situated almost immediately above the antheridium, not by its side (the usual position in *Chara*), and is therefore only at a slight diagonal to the branchlet-node, while the other bracteole is below the base of the antheridium a little to one side, and appears like one of the bract-cells, than which it is but little smaller. Whatever may be the explanation of this curious deviation from the normal relative position of the gametangia, it is certainly not "for convenience of packing," for when, as very frequently happens in the Mauritian plant, there are two pairs at a branchlet-node, the two sexes alternating, the one oospore is tightly wedged in between the two antheridia.

The Mauritian plant, which may be provisionally designated *forma mascarensis*, is a rather slender form, but in other respects a particularly vigorous one, fruiting at the lowest free branchlet-nodes more profusely than in the type, and usually, not as an exception, producing a ring of bract-cells below the final segment. The stipulodes, too, are more numerous than we have seen in the typical forms, placing it in the section *Bistipulatae* rather than in *Unistipulatae*, where it was located by Braun. This character does not, however, seem a sufficiently stable one to afford a basis for the primary division of the *Haplostephanae*.

C. corallina has never been adequately figured, and it is such a remarkable species that, although not new, we have thought it worth while to give an illustration of it, more especially to show the position of the gametangia.

C. tanyglochis, H. and J. Groves, Journ. Linn. Soc., vol. xxxvii, p. 286, t. 11 (1906).

I. i. Cape. Cape Flats, near Cape Town, near Ronde Vlei, E. L. S. 27, and vleis beside Lansdowne Road, Dec. 1921, E. L. S. 73 and 74; Vryburg, Armoed's Vlakte, alt. 3960 ft., Sept. 1921, A. O. D. Modd [8868B].

I. iv. Transvaal. Johannesburg, alt. 5700 ft., boggy pools and slow stream at Killarney, May and August 1923, M. A. Pocock (E. L. S. 134 and 178), and at Florida, Aug. 1923, M. A. Pocock (E. L. S. 177).

This well-marked endemic species was only previously known from Muizenberg Vlei, near Cape Town, where it was discovered by Col. Wolley-Dod.

C. chrysospora, sp. nov. (Plate XV, figs. 1–7.)

Diplostephana triplosticha phloeopodica monoecia. Caulis tenuis, maturitate regulariter triplostiche-corticatus; aculei rudimentarii. Stipulodia seriei superioris modice elongata acuminata, seriei inferioris multo breviora vel paene rudimentaria. Ramuli ecorticati vel partim diplostiche-corticati, gamentangiis super segmenta ecorticata frequenter gerentibus. Oospora crocea.

Monoecious. Stem slender (diameter c. 500 μ); cortex ultimately regularly triplostichous, smooth, cells of both series about equal, the secondary not tapering much at their extremities; spine-cells rudimentary, sometimes hardly visible; whorls of 8–10 branchlets. Stipulodes of the upper series well developed, of moderate length, acuminate; of the lower much shorter or almost rudimentary. Branchlets slender, of 6–7 segments, ecorticate or partially diplostichously corticate, the ultimate segment elongate conical acuminate. Bract-cells normally 5, variable in length, the anterior pair sometimes exceeding sometimes falling short of the fruit, the second pair shorter, the posterior bract-cell very short or rudimentary; bracteoles usually exceeding the fruit; bract-cells and bracteoles acuminate; a shorter cylindrical cell, similar to the bract-cells, sometimes produced below the antheridium, or below the oogonium when no antheridium is present. Oogonia produced at the lowest 2–4 branchlet-nodes, sometimes geminate, 600–700 μ long (excluding coronula), 375–450 μ broad; spiral-cells showing 12–13 convolutions; coronula straight or slightly spreading, c. 150–200 μ high, 225–250 μ broad. Oospores ellipsoid, c. 375–500 μ long, 250–300 μ broad, brilliant orange, showing 11–12 thin well-marked ridges; membrane very thin, transparent, light golden-yellow finely granulate. Antheridia $\rightarrow$ 375 μ in diameter.

I. i. Cape. Cape Flats, near Cape Town, among dunes near Riet Vallei, Nov. 1921, E. L. S. 63 (immature), and vleis beside Lansdowne Road, Dec. 1921, E. L. S. 70.

A rather small slender plant, sometimes producing long spreading branchlets (see fig. 2). Its outstanding features are the irregularly corticate branchlets, gametangia being often produced above ecorticate segments, the well-developed acuminate upper stipulodes, and the beautiful golden-orange oospores. The occurrence of the elongated cell analogous to the bractlet of dioecious species is remarkable, but may prove to be an individual peculiarly being present at some only of the nodes. At many fertile nodes no antheridia are present.

From *C. fragilis*, Desv., and its near relative *C. delicatula*, Agardh, *C. chrysospora* is at once distinguished by the colour of the oospore, the much smaller size of the gametangia, and the imperfect cortication of the branchlets; from the former also by the well-developed upper stipulodes, and from the latter by the equal diameter of the cells of the stem-cortex. The other monoecious species of the section which come nearest to the present plant are *C. Schroederi*, Migula, from Nairobi (Div. IX) and *C. leptosperma*, Braun, from Mexico. We have not seen authentic specimens of either of these, but they would appear to differ from *C. chrysospora* as follows: *C. Schroederi* in having rudimentary upper stipulodes and much larger gametangia, *C. leptosperma* in having a well-developed branchlet cortex, long lower stipulodes, short bluntish bract-cells, and an elongated connivent coronula.

C. pseudo-brachypus, sp. nov. (Plate XV, figs. 8–12.)

Diplostephana triplosticha phloeopodica monoecia. Caulis tenuis; corticis cellulis primariis et secundariis fere aequalibus; aculeis interdum elongatis, acuminatis vel obtusiusculis. Stipulodia seriei utrisque valde evoluta tenues, plerumque acuminata. Ramuli pq. 10, *diplostiche corticati. Oospora fere atra.*

Monoecious. Stem slender (diameter c. 500 μ); cortex triplostichous cells of the primary and secondary series of about equal diameter, spine-cells solitary, scarcely spreading, very variable in length, sometimes acute or acuminate, sometimes somewhat obtuse. Whorls of about 10 branchlets. Stipulodes of both series well developed, long, the upper longer than the lower, usually acuminate. Branchlets of about 7 segments, the upper 2–3 ecorticate, the lowest often somewhat abbreviated; cortex diplostichous, the cells often tumid. Bract-cells normally 7, the anterior pair often alone elongated and equalling or slightly exceeding the fruit, the others much shorter or quite rudimentary; bracteoles rather shorter than the anterior bract-cells. Oogonia produced at the lowest 2–3 branchlet-nodes, usually

c. 600–700 μ long (excluding coronula), 400–500 μ broad; spiral cells showing 11–14 convolutions; coronula c. 175–225 μ broad, 75–100 μ high, straight or slightly spreading. Oospores usually c. 475–600 μ long, 325–400 μ broad, very dark warm brown to almost black, showing 10–13 firm low ridges terminating in short claws; membrane thick, almost opaque, brittle. Antheridia c. 325–350 μ in diameter.

I. ii. Natal. In swamp, Umkomaas, at 4000–5000 ft., April 1892, J. Medley Wood, 4595B (Herb. Kew).

IV. Southern Rhodesia. In swamp, Salisbury, at 4800 ft., Feb. 1920, F. Eyles, 2089.

C. pseudo-brachypus resembles in appearance a weak form of *C. brachypus*, Braun. Both Mr. Wood's and Mr. Eyles's specimens show a small tufted plant only a few inches high, with short internodes, and Mr. Eyles refers to it as forming a large dark-green cluster. It approaches *C. brachypus* in the numerous branchlets, long sharp stipulodes, more or less elongated, usually acute spine-cells, and often somewhat turgid cortex to the branchlets, but differs in having a diplostichous branchlet cortex and less abbreviated lowest branchlet-segment. From *C. fragilis* it differs in the more numerous branchlets, well-developed acute stipulodes, often elongated spine-cells and smaller antheridia. The stem-cortex is variable, sometimes irregularly sometimes quite regularly triplostichous. The spine-cells vary considerably in length, some being as long as 1 mm., slender and acuminate, some quite short. The size and shape of the fruit is also variable; in the Natal plant a few of the oospores are almost spherical, measuring in breadth as much as 525 μ.

EXPLANATION OF PLATES.

PLATE XII.

Nitella praeclara, sp. nov.

1. ♂ plant, nat. size.
2. ♀ do., both from Cape Flats (E. L. S.).
3. Young plant with proembryos, nat. size.
4–7. Fertile branchlets (4 ♂, 5–7 ♀), after H. Groves. × c. 25.
8. Apex of sterile branchlet, after H. Groves. × c 25.
9. Oogonium. × c. 40.
10. Coronula. × c. 150.
11. Oospore. × c. 45.
12. Oospore membrane. × c. 300.

PLATE XIII.

Nitella Doidgeae, sp. nov. (figs. 1–10), from Belfast, Transvaal (E. M. Doidge).

1. ♂ plant, nat. size.
2. ♀ do.
3. Upper whorls, ♂. × c. 7.

4. Upper whorls, ♀. × c. 7.
5–6. Upper part of dactyls with usual types of apical cell. × c. 40.
7. Do., showing exceptional type. × c. 40.
8. Upper part of branchlet with oogonium. × c. 65.
9. Oospore. × c. 65.
10. Oospore membrane. × c. 250.

N. divaricata, sp. nov. (figs. 11–19), from Belfast, Transvaal (E. M. Doidge).

11. Lower whorls. × c. 7.
12. Upper (fertile) whorls. × c. 7.
13. Portion of fertile branchlet. × c. 30.
14–16. Upper parts of sterile branchlets. × c. 50.
17. Oogonium. × c. 40.
18. Oospore. × c. 45.
19. Oospore membrane × c. 250.

Plate XIV.

Chara corallina, Willd., f. mascarensis, from Mauritius (E. F. S. Shepherd).

1. Plant, nat. size.
2. Base of young whorl, viewed from above. × c. 14.
3. Base of more mature whorl, side view. × c. 14.
4. Fertile node of branchlet, side view. × c. 22.
5. Do., viewed from above. × c. 22.
6. Sterile node of branchlet, viewed from above. × c. 22.
7–8. Apices of branchlets. × c. 30 (7 usual, 8 occasional).
9. Apex of oogonium, with coronula. × c. 40.
10. Oospore. × c. 30.

Plate XV.

Chara chrysospora, sp. nov. (figs. 1–7), from Cape Flats (E. L. S.).

1. Plant, nat. size.
2. Portion of form with long spreading branchlets, nat. size.
3. Do. stem with base of whorl of branchlets, some corticate, some ecorticate. × c. 32.
4. Fertile branchlet-node. × c. 30.
5. Apex of branchlet. × c. 35.
6. Oogonium. × c. 35.
7. Oospore. × c. 35.

Chara pseudo-brachypus, sp. nov. (figs. 8–12), from Salisbury, Rhodesia (F. Eyles).

8. Plant, nat. size.
9. Portion of stem with base of whorl. × c. 32.
10. Fertile branchlet-node. × c. 35.
11. Oogonium. × c. 35.
12. Oospore. × c. 35.

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NITELLA PRAECLARA.

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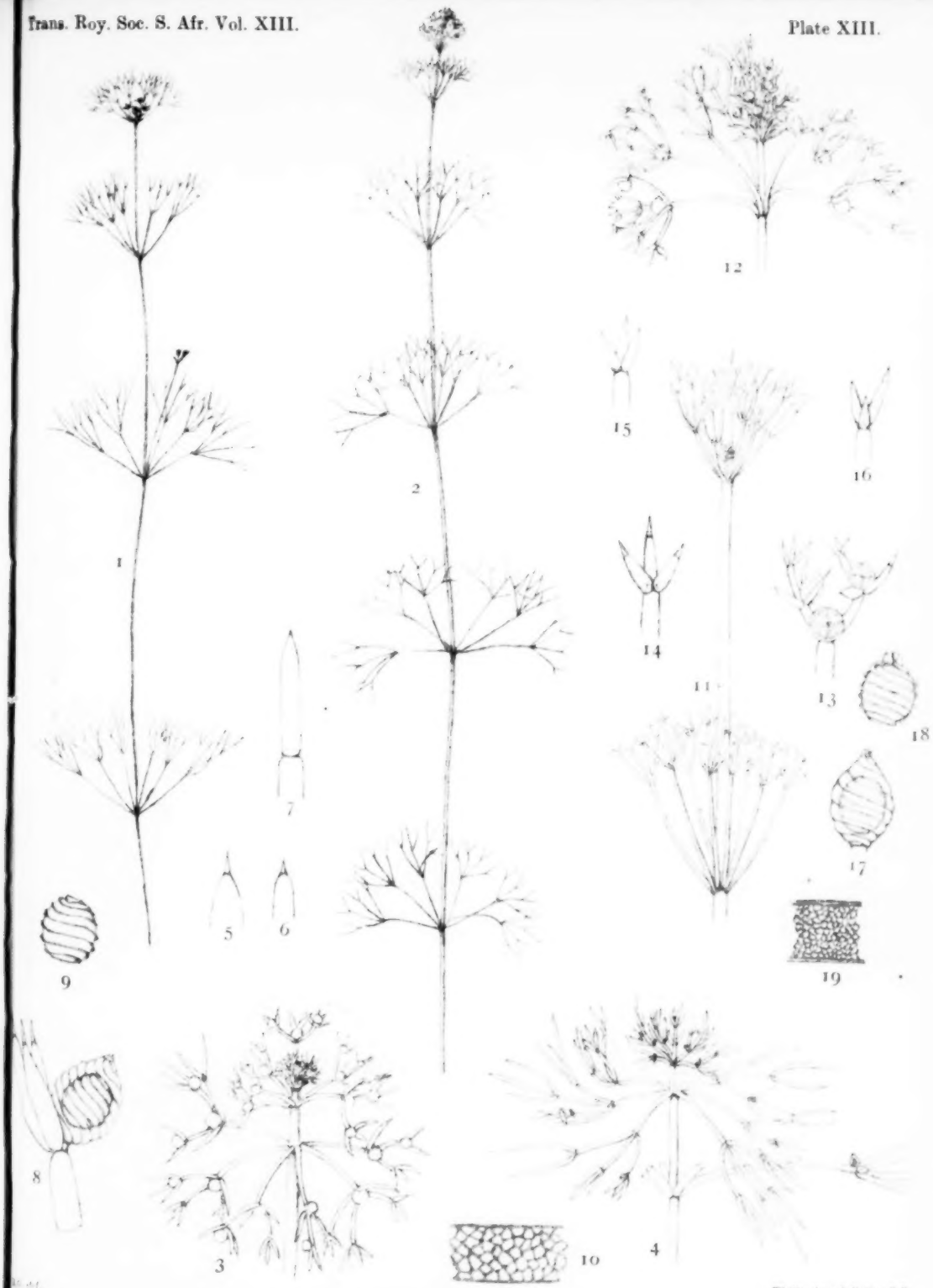

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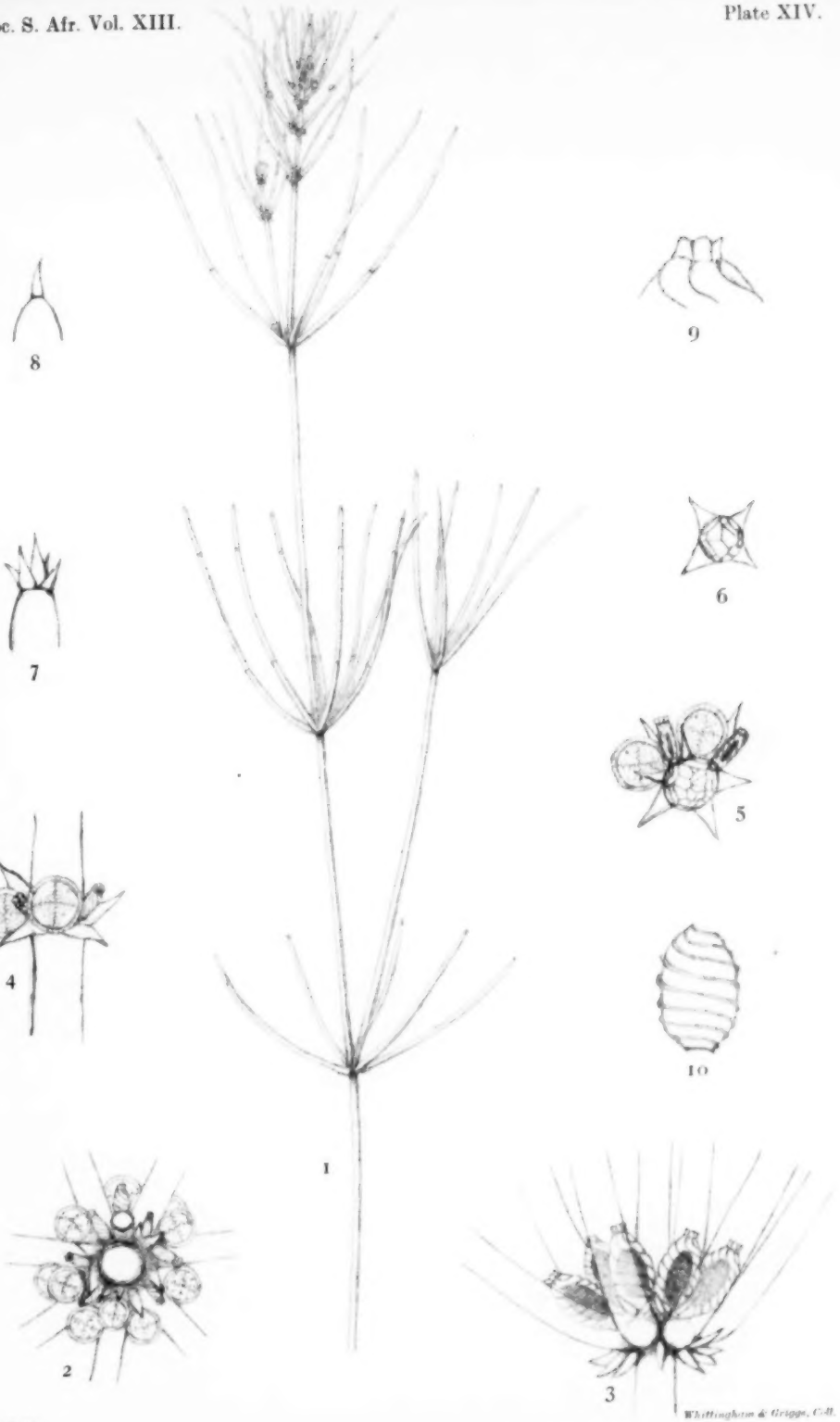
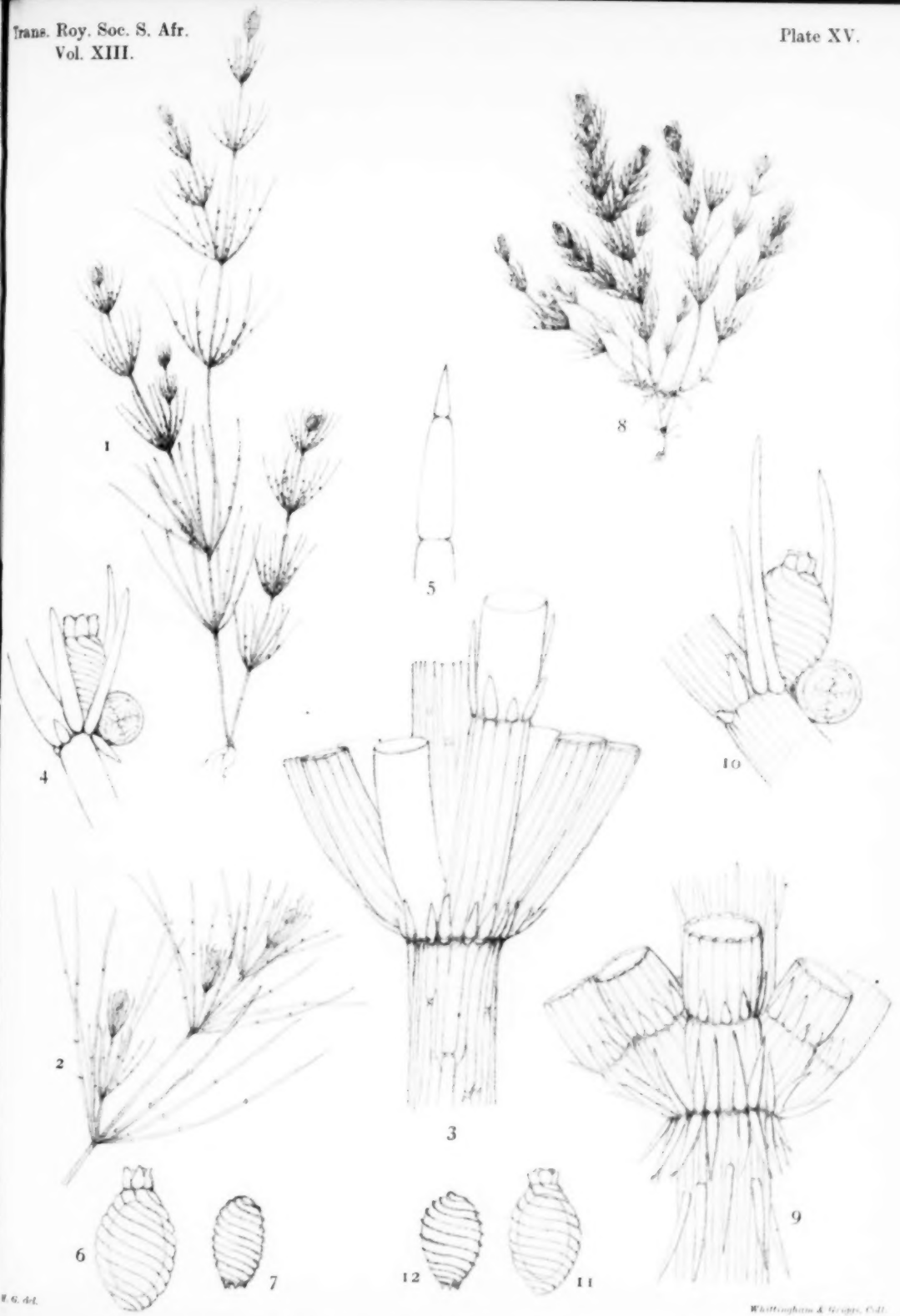
NITELLA DOIDGEAE, 1-10. N. DIVARICATA, 11-19.



CHARA CORALLINA, F. MASCARENSIS.



CHARA CHRYSOSPORA, 1-7. C. PSEUDO-BRACHYPUS, 8-12.

ON SOME NEW MOLLUSCA FROM TERTIARY BEDS IN THE WEST OF THE CAPE PROVINCE.

By S. H. Haughton, B.A., D.Sc.

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(With Plates XVI–XVIII.)

In the course of an extensive survey of the coastal deposits of the Union of South Africa, Mr. A. V. Krige, M.Sc., of the University of Stellenbosch, has collected a large number of shells at certain localities, and these he has been good enough to submit to me for identification. Perhaps the most interesting assemblage is that obtained from Doorn Baai on the west coast, and it is the purpose of this paper to describe some forms, new to our fauna, which point to a Mio-Pliocene age for some at least of the west-coast deposits.

Mr. Krige has also been good enough to supply me with details of the stratigraphy of the fossiliferous deposits of the area from which the shells came ; this account is given here before the actual descriptions.

The shells to be described come from a deposit at Doorn Baai on the Vanrhynsdorp coast south of the Olifants River mouth. The beds, which average about 10 feet in thickness, form the upper portion of marine cliffs, which attain a height of 50 to 60 feet above sea-level along Doorn Baai and southward to Donkin's Bay, but rise to 100 feet and over at the north end of Doorn Baai, maintaining this height northward for three miles to the beach at Strandfontein. Between Bamboesbaai and Strandfontein, the Table Mountain Sandstone, which everywhere underlies the deposits, dips eastwards at angles varying from 10° to 45°, and forms cliffs of a rugged grandeur unparalleled along the west coast of the Province, and perhaps best matched by those of Cape Infanta. The difference in altitude of the cliffs and the conspicuous terrace behind them is due to uneven uplift, producing at the northern end of Doorn Baai a southerly dip of 3° to 4° in the " beach deposit." The terrace, which is doubtless a covered plane of marine denudation, extends inland for a mile to the foot of a range of sandy hills showing occasional outcrops of Table Mountain Sandstone. It extends southwards from Doorn Baai for about ten miles, with an average altitude of

50 feet at its seaward edge. Northward it becomes a narrower feature, until beyond Strandfontein the inland rise is more rapid owing to a thicker covering of bedded red sands, which replace the older beach deposit and attain a maximum height of 250 feet at the coast about nine miles north of the Olifants River mouth. For a distance of twelve miles north of Strandfontein the numerous headlands of Malmesbury phyllites show the peneplaned surface at 60 feet. Further north along Geelwal Karroo the Malmesbury headlands attain a height of 70 feet. Still further north along Klipvlei an isolated beach deposit only one foot thick overlies gneiss at a height of 30 feet above sea-level. This shelly bed of calcareous sandstone, which is only about 30 yards long, is tilted seaward at 3° to 4°. It contains shells identical with some of those from Doorn Baai. This diminutive northern representative of the Doorn Baai deposit points to a more extensive area of deposition, and perhaps to further evidence of unequal uplift.

The nature of the deposits covering the terrace has been described by Dr. Rogers (Report of the Geological Commission, 1903), and again by Rogers and du Toit in their Geology of Cape Colony. The shells occur mainly in a calcareous conglomeratic sandstone which lies upon ferruginous sandstones and also passes laterally into hard siliceous conglomerates. Silicification has, apparently, proceeded unevenly, and when complete has obliterated all trace of fossils.

Description of Species.

Mytilus tomlini, sp. nov.

Two specimens of this form are figured, of which the larger may be taken as the type. The other, which has an abnormal shell-growth in the area of the hinge, is looked upon as a malformed individual.

The species is of large size. The type has a length of 175 mm., a height of 80 mm., and a thickness of 42 mm. The dorsal edge is regularly convex, the ventral edge arcuate. Shell thick, its external surface marked by distinct strong concentric undulations; posterior portion of shell considerably thinner, and marked by well-developed, closely arranged growth-lines. Beak terminal. Hinge ridge long and narrow.

The shell is much heavier than, and quite distinct from, the common *Mytilus edulis* now living along the west coast, and has been named in honour of Mr. J. R. le B. Tomlin, who is engaged upon a revision of the South African Marine Mollusca.

Donax (*Iphigenia*) *rogersi*, sp. nov.

As co-types of this form I take two separate valves, one right valve and one left valve, from Doorn Baai. The features can best be discerned from the photographs. Measurements are as follows:—

	Left valve.	Right valve.
Length . . .	132 mm.	125 mm.
Height . . .	92 ,,	83 ,,
Thickness . . .	26 ,,	24 ,,

The left valve is thus slightly higher than the other in proportion to its length.

Shell large, equivalve, inequilateral, elongate, anterior end broadly rounded, posterior end more acute. Shell thick. Umbones small, slightly incurved, behind mid-line of shell. A well-defined ridge runs from the umbo to the posterior angle, separating outer face of shell into two very unequal parts, the posterior of which lies in a transverse plane. Shell smooth, except for concentric growth-lines. External border entire, not serrated.

Cardinal teeth prominent, not bifid; lateral teeth obsolete. Nymph prominent and strong. Ligament external, opisthodetic, lying in an arc-shaped groove. Pallial sinus deep and high.

A very distinct species, named in honour of Dr. A. W. Rogers, who was the first to examine the Doorn Baai deposits.

Chamelea krigei, sp. nov.

There are a number of specimens of a form of *Chamelea* which seem to be new, and which I propose to name after Mr. A. V. Krige. The species is a variable one, allied to *C. rogersi*, described by Bullen-Newton from the Alexandria Beds of Redhouse, C.P. From that species, however, all the varieties seem to differ in that the border of the shell just in front of the umbo is more deeply concave, so that in external view the umbo apparently slopes more steeply forward. In dentition and external sculpture the two species are very close.

Three varieties of *C. krigei* may be distinguished in the material at our disposal, viz. (1) a short rounded variety which may be called var. *circularis*; (2) an elongate, more compressed variety which may be called var. *elongatus*; (3) a third variety, intermediate between the others, to be known as var. *intermedius*.

Measurements of the types of these three varieties are given in table on p. 162.

It is interesting to note that the heaviness of the hinge area decreases regularly as one passes from the short and high individuals to the elongate form.

	var. *circularis*.	var. *elongatus*.	var. *intermedius*.	
	Type.	Type.	Co-type A.	Co-type B.
Length . . .	47 mm.	57 mm.	47 mm.	55 mm.
Height . . .	49 ,,	48 ,,	44·5 ,,	50 ,,
Thickness . . .	19 ,,	16 ,,	16 ,,	17 ,,
Height, base of hinge-line to umbo . . .	9 ,,	7 ,,	7·5 ,,	8 ,,

Age of Deposits.

Associated with the new species of shells described above are a number of forms of *Patella*—all living in the neighbouring waters to-day,—many specimens of the gasteropod *Cominella limbosa*, and fragments of a very thick and large form of *Ostrea*. That the conditions under which the deposits were laid down were different from those of the present coast is apparent; but the presence of living species prevents us from considering the beds as of early Tertiary age. The similarity of *C. krigei* to *C. rogersi* warrants the suggestion that the age of these Doorn Baai deposits may be the same as that of the Alexandria Beds of Redhouse, which Bullen-Newton considered as Mio-Pliocene. The evidence of differential uplift adduced by Mr. Krige renders it possible that the difference in level between the beds of Redhouse (200 feet above sea-level) and those of Doorn Baai is not necessarily an argument against their contemporaneity.

EXPLANATION OF PLATES.

Plate XVI.—*Mytilus tomlini*, sp. nov.

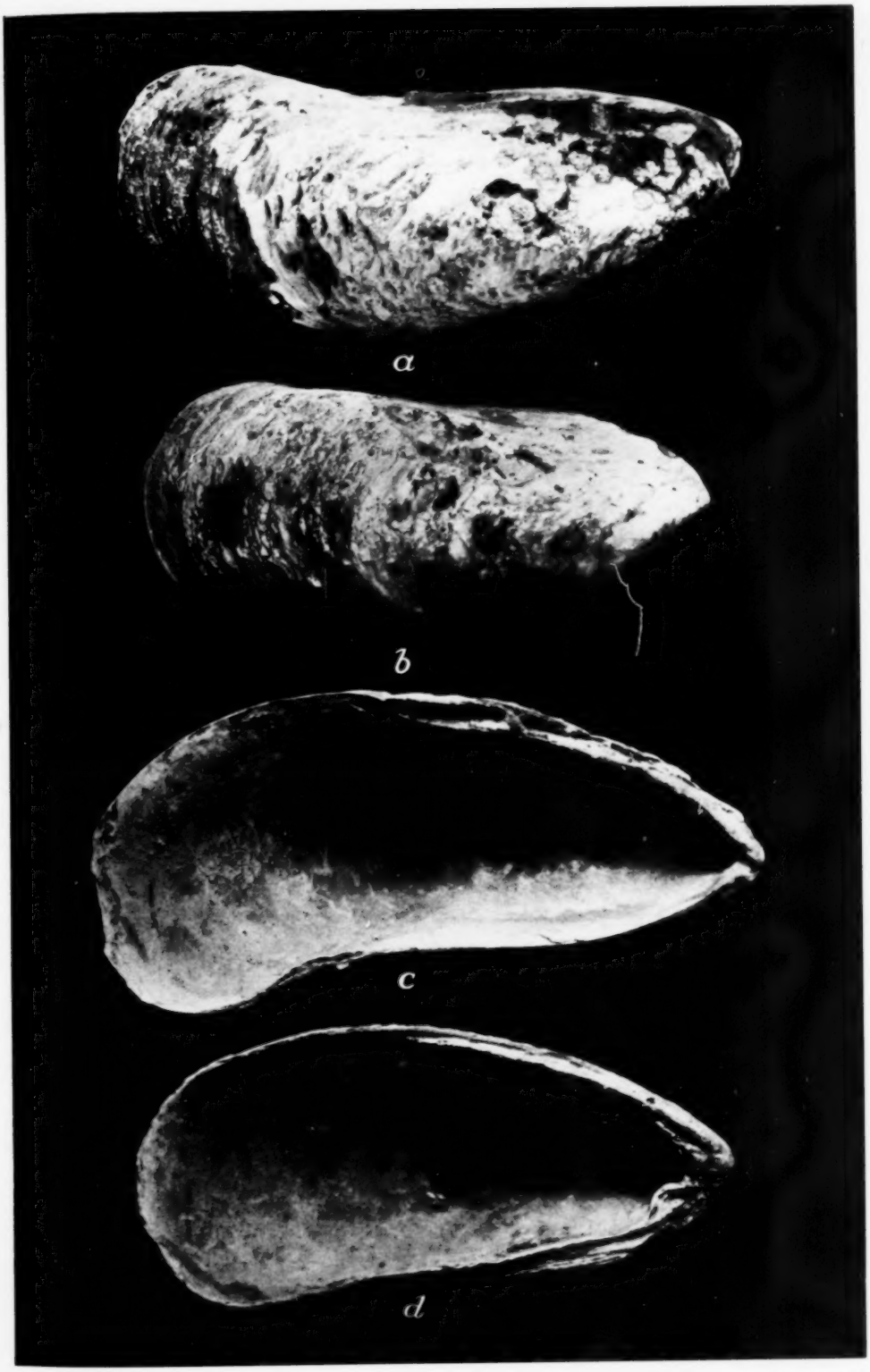
a, External view of type; *b*, external view of malformed specimen; *c*, internal view of type; *d*, internal view of malformed specimen.

Plate XVII.—*Donax* (*Iphigenia*) *rogersi*, sp. nov.

a, External view; *b*, umbonal view; *c*, internal view of type, left valve.

Plate XVIII.—*Chamelea krigei*, sp. nov.

Var. *circularis*, nov. *a*, Internal view; *f*, external view.
Var. *intermedius*, nov. Co-type A. *b*, Internal view; *e*, external view.
Co-type B. *c*, Internal view; *h*, external view.
Var. *elongatus*, nov. *d*, Internal view; *g*, external view.



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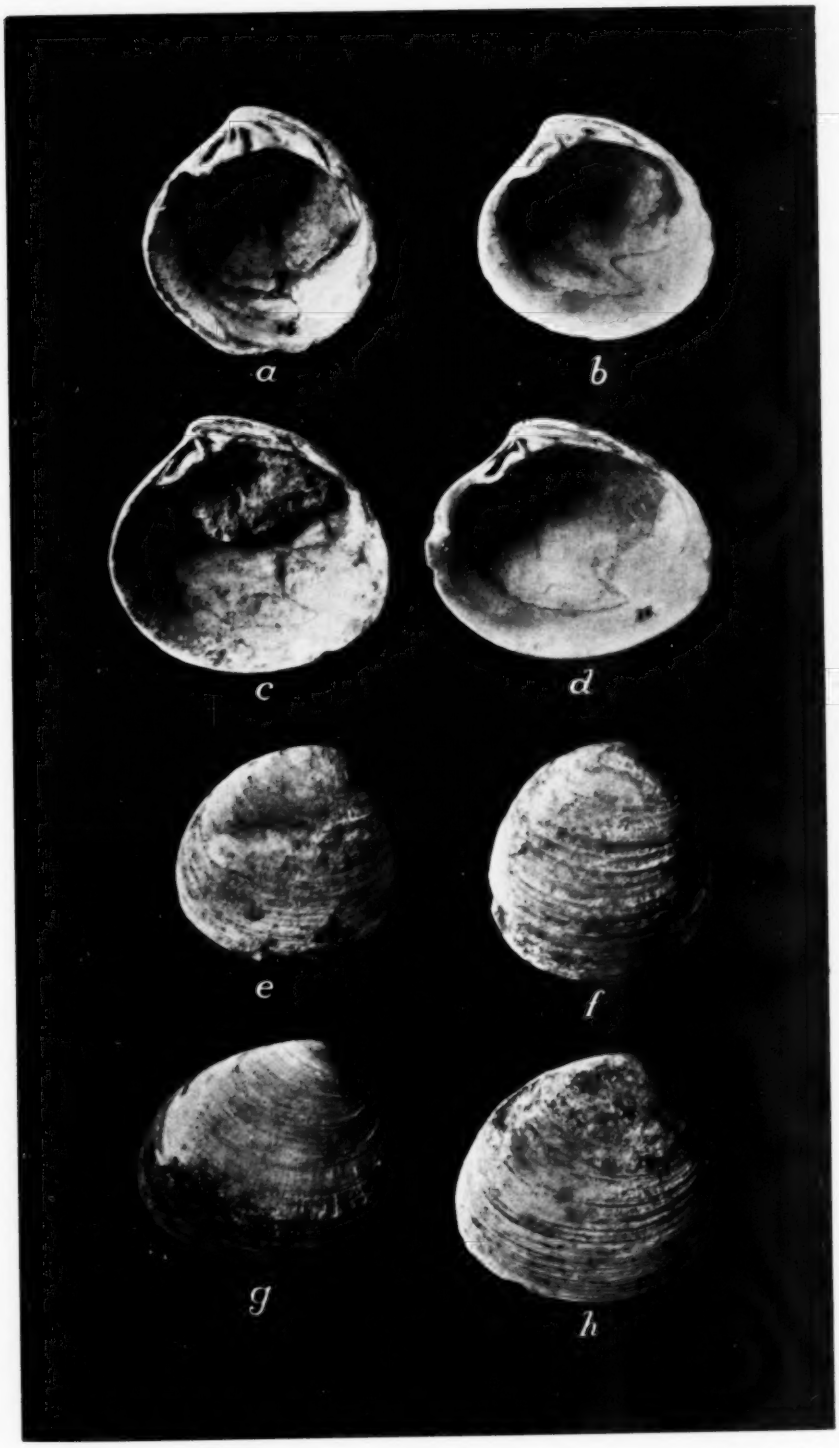

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THE BREEDING HABITS AND LIFE-HISTORIES OF SOME OF THE TRANSVAAL AMPHIBIA.

By Vincent A. Wager, B.Sc.

(With eight Text-figures.)

Introduction.

The life-histories and breeding habits of the following Transvaal Amphibia have been fully worked out by the present writer, with the exception of the last four, a few stages in the life-histories of which are missing. These are, however, hoped to be obtained shortly. The first two are here described fully, and the rest will follow as soon as possible.

Chiromantis xerampelina.
Rappia marmorata.
Bufo regularis.
Bufo carens.
Cassina senegalensis.
Phrynobatrachus natalensis.
Xenopus laevis.
Pyxicephalus adspersus.
Rana angolensis.
Rana fasciata.
Pyxicephalus delalandii.
Pyxicephalus rudii.
Heleophryne sp. (probably new).

Terms used in Description.

Distance between eyes=distance from centre of lens of one eye to centre of lens of other.

Distance between nostrils=distance from centre of one nostril to centre of other nostril.

Angle between eyes and nostrils=angle between line joining eye and nostril, and line between eye and eye.

$$\textit{Eye nostril index} = \frac{\text{distance between nostrils}}{\text{distance between eyes}} \times 100 \text{ per cent.}$$

Distance of eyes from snout=perpendicular distance of line joining eyes, from tip of snout.

End of body=point at which anal tube leaves the body, not including passage through tail fin.

The sizes selected for description are not particularly well-marked "stages," but were chosen on account of being the commonest sizes amongst the collected material.

Chiromantis xerampelina.

Specimens collected at Gravelotte, January 1925.

Adult Frog.

Chiromantis xerampelina is a tree-frog which is about 2 inches in length in the adult form, and whose terminal phalanges support discs or suckers. Its distinguishing feature is the peculiar arrangement of the fingers, the first and second being opposed to the others.

Distribution.

The distribution of this species is restricted to British East Africa, Rhodesia, Portuguese East Africa, and the Transvaal.

Breeding Habits.

In the breeding season the animals gather in the trees and bushes in the vicinity of pools and streams, when they emit a subdued squeaking noise which sounds like "Chick, chick a chick, chick." The first rains of the season seem to be the signal for their first appearance, and the breeding season continues throughout the summer, eggs being laid only after each rainstorm. The breeding season thus lasts more or less from October to February. The eggs are laid in the midst of a large foamy mass of white substance which greatly resembles the beaten white of a hen's egg (see figs. 4 and 5). This white frothy substance glitters in the sun, is very sticky, and readily adheres to the fingers on being touched. The average size of each egg-mass is about 9 or 10 inches in diameter. In spite of its frothy nature each mass has a certain rigidity, and the sun's rays soon form a thin hardened crust around it. The egg-masses are usually deposited on branches which overhang water, and are held in position by the sticky nature of the froth. The eggs are laid on various kinds of objects, and at various heights, ranging from a few inches to many yards, above the water. A favourite position is on the trunk of a tree or from the underside of a big branch overhanging a pool; but the egg-masses were also found on the tips of branches, attached to the twigs and leaves, on small shrubs, grasses

and reeds, and, in fact, on any suitable object projecting from or overhanging the water. One mass was found on the edge of a petrol tin standing in the middle of a shallow pool. Stagnant pools are preferred, but the egg-masses were also occasionally found overhanging fairly fast-flowing streams. In one pool under observation, a certain dead tree trunk bending over a few feet from the water was a great favourite, and after each of the numerous rains during six weeks it had three or four fresh masses of eggs on it. The parents appeared to show great sagacity in choosing the situation, for in many cases only one small part of the tree overhung the water—in one special instance over 60 feet above the water—and this part was always chosen.

Eggs.

The eggs are of a dense uniform white colour and are 1·8 mm. in diameter. There are about 150 in each egg-mass, in the centre of which they lie somewhat scattered.

Incubation and Tadpoles.

Within three or four days the tadpoles are formed, and have large external gills. They wriggle around and collect together in a squirming mass which slowly sinks to the bottom of the egg-mass, which has become slightly more liquid inside. At about the fifth day the tadpoles have reached the bottom of the egg-mass, which then gives way, and the majority of the young larvae fall together into the water below. On touching the water the tadpoles immediately swim rapidly away in all directions. Those left in the white mass slowly wriggle down until they reach the bottom, and then drop into the water. The empty egg-mass now dries into a hard empty vacuolated foamy white mass of almost the same volume as before, and as it is very readily soluble in water is washed off by the next rain.

Newly-hatched Tadpole.

From tip of snout to end of tail measures 9 mm.

The tail is twice as long as the body.

Large external gills are present.

Slightly older Tadpole—measuring 13 *mm.*

Tip of snout to end of body is 5 mm.

End of body to end of tail is 8 mm.

Body is oval in shape, slightly pointed anteriorly towards the mouth.

Mouth is situated on underside almost at tip of head.

Jaws of the mouth are black and horny.

On upper lip there is one transverse ridge bearing a row of tiny black horny teeth and the beginnings of another similar ridge between the first

and the upper jaw. This second ridge is in two parts which grow towards one another, later to form a complete ridge.

There are three ridges of similar comb-like teeth on the lower jaw.

Around the mouth on the sides are a number of papillae.

Eyes are situated fairly close together on the top of the head and are about one-third of the length of the body from the tip of the snout, *i.e.* 1·2 mm.

Upper fin arises on opposite side of and slightly in front of the level of the anus, about 2·7 mm. from the eye.

Greatest depth of the tail fin is about 2·5 mm. at about one-third length of tail from the posterior end, *i.e.* about 2·6 mm.

These measurements vary slightly in different specimens of the same size.

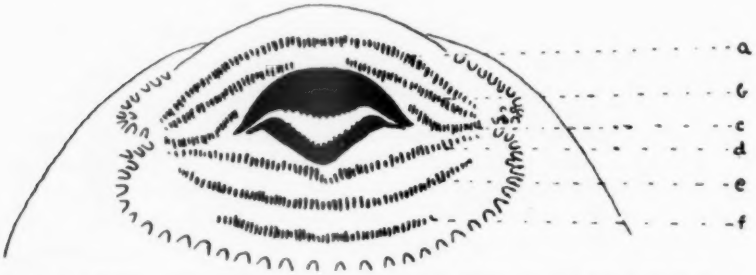


FIG. 1.—*Chiromantis xerampelina.* Mouth of tadpole, 18 mm. long. Row *a* has 71 teeth, *b* has 59 teeth, *c* has 43 teeth, *d* has 56 teeth, *e* has 57 teeth, *f* has 46 teeth.

Tadpole—18 *mm. long.*

Two tiny buds of the hind legs appear, one on each side of the anus.

Mouth (see fig. 1). The second row (*b*) of horny teeth is very nearly complete, while two parts of a third row (*c*) have appeared between the second and the jaw. There are over 300 horny teeth in all.

Tadpole—42 *mm. long.*

Tip of snout to end of body is 15 mm.

End of body to tip of tail is 27 mm.

Distance between nostrils is 2·1 mm.

Distance between eyes is 5·5 mm.

Distance between eyes and nostrils is 3·1 mm.

Angle between eyes and nostrils is 57°.

Eye nostril index $=\frac{2\cdot1}{5\cdot5}\times100=38$ per cent.

Mouth, second row on upper side, is complete, except for a very small gap in the middle, while the third row is still composed of two parts.

Tail at deepest point is 10 mm. at a point 6 mm. from end of body.
Legs are very small, but the discs on the toes are clearly visible.

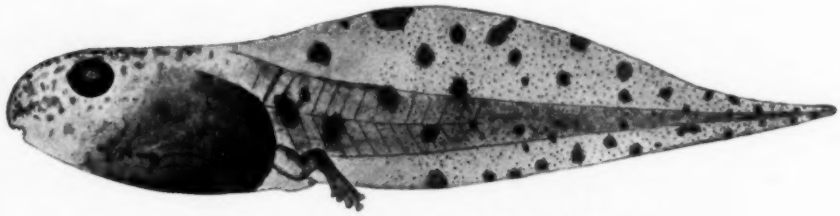


FIG. 2.—*Chiromantis xerampelina.* Tadpole, 52 mm. long.

Tadpole—52 mm. long. Full grown. (See fig. 2.)

Tip of snout to end of body is 18 mm.

End of body to end of tail is 34 mm.

Top of head between eyes is flat and falls away immediately to the sides, so that the lenses are nearly vertical.

Body has become slightly larger, but the eyes have not shifted further back, so that they are still less than one-third distance from snout to end of body.

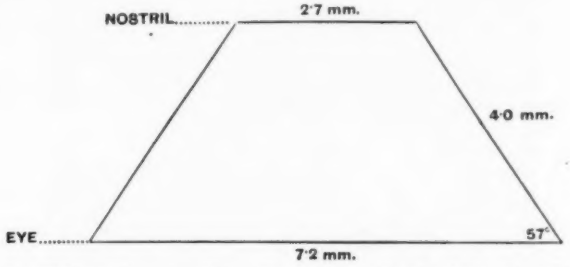


FIG. 3.—*Chiromantis xerampelina.* Eye nostril angle of tadpole, 52 mm. long.

Distance between nostrils is 2·7 mm.

Distance between eyes is 7·2 mm.

Distance between eyes and nostril is 4·0 mm.

Angle between eyes and nostrils is 57°.

Eye nostril index=$\frac{2\cdot7}{7\cdot2}\times100=37\cdot5$ per cent. (see fig. 3).

The horny jaws have two complete rows of comb-like teeth and two small portions of a third row on the upper side, and three complete rows on the lower side.

There are roughly about 500 small horny teeth altogether.

Fleshy papillae occur on the lips at the sides of the mouth, but do not completely encircle the latter.

Dorsal tail fin leaves the body not directly over the vent, where ventral fin begins, but about one-fifth length of head and body anterior to the anus.

Near its end the tail is very narrow and curves slightly upwards, ending in a fairly sharp point.

[*Photo by V. A. Wager.*

FIG. 4.—Egg-masses of *Chiromantis xerampelina* in natural surroundings.

Width of body at point where upper fin leaves body is about 10 mm.

Spiracle is a small opening on the left side of the tadpole, and is situated on the corner of the bottom and side of the body. The opening is level with the body and does not form a projecting funnel. Centre of the opening is 10 mm. from tip of snout, 11 mm. from end of body, and is 5 mm. from line joining mouth and anus (see fig. 2).

Coloration. The tadpole is a mottled brownish-black colour, small patches of the tail being slightly darker than the rest. The body is of a darker hue, owing to the contents of the alimentary tract.

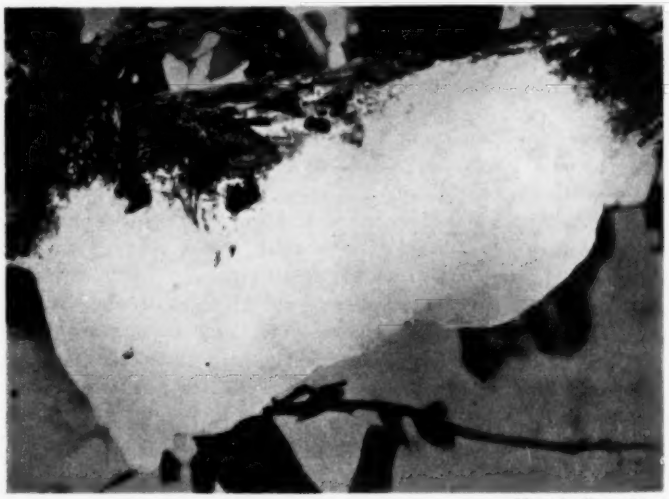
The hind legs are well developed, with the discs on the toes very distinct.

The front legs, with suckers on the toes, can be seen lying in the gill chamber.

The ventral wall of the body is transparent, and the spirally coiled intestine can be seen beneath it.

Metamorphosis.

The tadpole does not increase in size as it completes its metamorphosis. The front legs break through the operculum, and the tail begins to decrease



[*Photo by V. A. Wager.*

FIG. 5.—A frog of *Chiromantis xerampelina* sitting just above a newly laid egg-mass.

in size. When the tail has practically vanished, the young frogs leave the water, and at this stage are very difficult to find. When they leave the water, the young frogs measure 16 mm. in length.

Rappia marmorata.

Specimens collected at Gravelotte, N.E. Transvaal, January 1925.

Adult Frog.

Rappia marmorata is a small tree-frog, the adult form of which becomes about an inch long. It has a very wide distribution, having been found in Rhodesia, Portuguese East Africa, South-West Africa, and South Africa, at Cape Peninsula, Port St. Johns, Kentani, Nelspruit, Gravelotte, etc. It is

a very pretty little frog ; the ventral side of the body and portions of the legs are of a pinkish colour, and there are four wide black stripes down the back on a white background. Great colour changes were noticed in these frogs, a few of which were kept in captivity. At times the black stripes became quite light, turning all shades of grey, till sometimes they were almost white ; while the original white stripes took on many different shades of yellow down to dark orange. These varying combinations of colour gave the frog quite a different appearance at different times. The frogs are difficult to find ; the few that were found were discovered sitting very quietly on reeds or leaves near pools of water. The vocal sac is folded up under the throat, but when inflated it bulges out enormously, while the animal emits peculiar squeaking noises.

Eggs.

The eggs vary very slightly in size and shape, but the average is between 1·3 and 1·4 mm. in diameter. Half of the egg is white in colour, the rest being brown. Each egg is embedded in a globular mass of jelly about 5 mm. in diameter. About 300 eggs are laid at a time, and the jelly of each being fairly rigid they all stick together in a fairly solid rounded mass up to 2 inches in diameter. The mass of eggs is generally entangled in a bit of grass which usually keeps the mass suspended a short distance beneath the surface of the water. The eggs were only found in stagnant pools and always just after a spell of wet weather, during December and January. Whether the breeding season goes on before or after these two months was not ascertained.

Incubation.

After about three days the small tadpoles are hatched and wriggle out of the mass of jelly.

Young Tadpole. About three days after leaving the jelly mass.

Total length is 9 mm.

Length from tip of snout to end of body is 3 mm.

Tail from end of body to tip is twice length of body.

Eyes are 1 mm. from tip of snout, *i.e.* one-third length of body.

The head is flat and the eyes are situated on the sides.

The mouth is broad and slit-like and is situated on the extreme front edge of the head. At the two corners of the mouth there appear to be the remains of two small round suckers.

A later Stage at which the Tadpole is 30 mm. long. Almost full grown.

Intermediate stages are, in comparison, same as full-size tadpole.

At all stages the tadpoles are very transparent, except in the region of

the abdomen, which is very dark coloured on account of the contents of the alimentary tract.

From tip of snout to end of body is 10 mm.

Tail is twice as long as body.

Body is broadest in region of the eyes, where it is 7 mm. wide.

Body is deepest in region of abdomen, where it is 6 mm. deep.

Eyes are 3 mm. from tip of snout, *i.e.* one-third length of body.

FIG. 6.—*Rappia marmorata.* Head of tadpole, 30 mm. long. (From above.)

Eyes are large, 1·6 mm. in diameter, and black and conspicuous against the transparent head.

Eyes are situated right on the edge on each side of the head, and the lenses are quite vertical.

Distance between eyes is 7·2 mm.

Distance between nostrils is 1·1 mm.

Distance between eye and nostril is 3·5 mm.

The eye nostril angle is 29° (see fig. 7).

The eye nostril index is $\frac{1\frac{1}{2}}{7} \times 100 = 15{\cdot}3$ per cent.

(This index varies slightly in different specimens.)

(Of seventeen tadpoles measured, each being under 30 mm. in length, the average size of the angle between eyes and nostril is 29°, the variations being from 25° to 34°. The average of eleven tadpoles, each measuring 30 mm. and over, was 30°, the variations ranging from 27° to 32°.)

The body converges to a point anteriorly and the mouth is a slit-like aperture at the anterior extremity.

The mouth is extremely peculiar in that it has no horny jaws, no rows of small comb-teeth, and no papillae, as are usually found in most other species. It is not hard or horny in any way, but soft, like the rest of the body.

The upper lip or jaw is flat and straight, and 2·5 mm. broad.

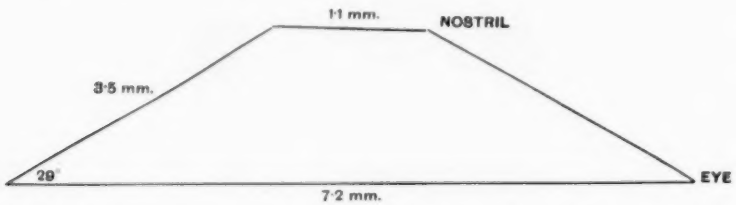


FIG. 7.—*Rappia marmorata.* Eye nostril angle (×2) of tadpole, 30 mm. long.

The lower lip is V-shaped, with the two arms of the V at a wide angle and the apex deep and rounded. The two arms of the V are attached somewhat within the mouth, while the rounded apex of the V projects slightly but conspicuously. When the tadpole is alive this lower lip can be seen moving in and out. The whole structure of the mouth is peculiar, and, as a rasping or biting motion is impossible, the diet of this species of tadpole probably consists only of diatoms and minute living organisms. This possibility is further borne out by the peculiar structure of the spiracle, which is large and would seem to permit of a large amount of water being sucked up, from which the micro-organisms could be abstracted.

The spiracle is a large median opening about 2 mm. wide, situated posteriorly and directly below the end of the body. The spiracle is tube-like for about 2 mm. from its end, the base of the tube being firmly attached to the body wall. The gill chamber is thus very large and seems to extend on the underside, all along the head and body. The anal tube is long, and passes obliquely through the centre of the ventral fin, so that its opening is about 3 mm. behind the spiracle opening.

The dorsal tail fin begins directly over the point where the body ends, and continues, except for a very slight upward trend, in a straight line

with the body. The tail fins have a uniform depth of about 6 mm. for a distance of about 7 mm. from the end of the body. They then taper fairly rapidly to a point about 6 mm. from the end of the tail. At this point the fin is about 1·5 mm. deep, and from there to the end it tapers very gradually and is whip-like. The tail fins are strongly pigmented with black, and sometimes red, in certain zones (see fig. 8). On the ventral fin there is a very dark-coloured black bank, about 0·5 mm. deep, running along the edge of the fin. Another black band, also about 0·5 mm. deep, runs parallel to and not quite touching the tail. Between the two bands there is a zone of light grey pigmentation, which may be often red. On the dorsal fin the coloration is similar to the lower, there being also two darker bands with a lighter zone between them, which may be red. The dark coloration of

Fig. 8.—*Rappia marmorata.* Tadpole, 30 mm. long. (From side.)
a = spiracle.

the tail fins stops abruptly about 7 mm. from the tip, both dorsal and ventral fins from that point to the tip being altogether devoid of pigmentation and transparent. The thin tail proper, which extends right to the very tip of the fins is, however, coloured and is whip-like. Thus the tail fins have the appearance of being broken off at the point where the pigmentation ceases. The head and body are heavily pigmented with black dots, more heavily in the middle of the back (see figs. 1 and 3).

The abdomen is very small and globular, and the spirally coiled intestine is covered over by a thin skin, very dark coloured. When uncoiled the intestine was found to be 90 mm. long, or three times the length of the tadpole. The contents of the anterior portion of the intestine consisted of a great diversity of minute organisms, the greater part of which were zygospores of Desmids and other Conjugatae. Naviculae, Bacillariae, Closteriae, Gleocapsae, Confervae, Euglenae, a large number of Volvox, and a few minute Annulates formed part of the tadpoles' diet.

The tadpoles are at first glance very similar to those of the Platana (*Xenopus laevis*), but the absence of the two tentacles at the sides of the mouth and the single median spiracle make identification easy.

Metamorphosis.

The tadpoles seldom grow longer than 30 mm., the longest measuring about 33 mm. The back legs grow larger, and the front legs can be seen on the sides of the body beneath the skin, just next to the anterior end of the abdomen. The toes and fingers all end in round suckers. Eventually the gill chamber splits in the region of the front legs, which are then pushed through the holes. Until the lungs are well formed, and the gills have lost their function, these two holes below the armpits serve as spiracular openings. The original spiracle immediately falls out of use and shrinks up. The head elongates, and even at this early stage the angle between the eyes and nostrils has increased to 43°. The mouth slowly becomes wider and the tail becomes shorter, while the stripes found on the adult make their appearance on the young frog. Tadpoles at this stage were extremely difficult to find, and where they disappeared to was a mystery, for, in spite of careful search in the pools, on the muddy banks, in reeds, grasses, trees, and under stones near the water, only very few were found.

Young frogs, when about to leave the water, measure 10 mm. in length.

ON THE ANATOMY OF SOME SHRUBBY IRIDACEAE.

By R. S. Adamson.

(From the Botanical Department, University of Cape Town.)

(With Plate XIX and nine Text-figures.)

The Iridaceae form one of the largest constituent families of the flora of the south-western portion of the Cape of Good Hope. In the number of genera and species this family ranks fourth in order of size in this region, and third in the more limited flora of the Cape Peninsula.* While the great majority of the plants included in the family are geophytes, there is a small group which have a habit quite unusual in the family, and indeed among monocotyledons as a whole. These plants have stiff erect stems which are woody and which have secondary growth. As far as is known at present, there are five species, representing three genera, that have this habit. All of them are endemic to the south-west Cape region.

Monocotyledons which have secondary growth in the stem have long been known.† The examples described belong, for the most part, to the Liliaceae, of which the best known are *Dracaena*, *Cordyline*, *Yucca*, and *Aloe*. Other genera with this feature in a less degree are *Gasteria*, *Haworthia*, and *Aprica*.‡ Among the Amaryllidaceae secondary growth occurs in *Agave* and in *Fourcroya*, and it is also known in the tubers of some of the Dioscoreaceae. Among the Iridaceae the stem of *Aristea corymbosa* has been described by Scott and Brebner § from material grown in the Botanic Gardens of Glasgow. Their descriptions and conclusions will be considered along with the descriptions of the material examined in the present study.

Distribution and Habit.

The plants belonging to the Liliaceae and Amaryllidaceae that have secondary growth all have a rather similar habit. They form a thick stem,

* Bolus, 1905. Bolus and Wolley-Dod, 1903.

† Haberlandt, 1914. De Bary, 1884. (Older works quoted here.)

‡ De Cordemoy, 1893.

§ Scott and Brebner, 1892

in most cases with few branches, and with short internodes. In many the growth in thickness of the stem is more pronounced than the growth in length. The tissues formed in the stem may be hard and fibrous, but do not have a really woody consistency. In these features they are in marked contrast to the shrubby Iridaceae which have been studied.

The plants that have been examined are *Aristea corymbosa*, *A. fruticosa*, *Witsenia maura*, *Klattia partita*, and *K. stokoei*. These plants occur naturally in wet situations. Of the five, *Aristea corymbosa* has the widest range. It occurs on the mountains from the Wellington district and the Witzenbergen as far east as the Groote Zwartebergen and Oudtshoorn. The others have a more restricted range, the limits on the east being the Langebergen near Riversdale, and on the north-west the Olifants River Mountains. *Witsenia* is the only one that occurs on the Cape Peninsula.

The habit in all these plants is exceedingly similar, so much so, indeed, that non-flowering specimens are not always easily differentiated. The stem is stiff and erect, with the branches distichous and ascending. The upper parts bear narrow equitant leaves arranged in a regular distichous manner. The bare part of the stem below the leaves has prominent leaf scars, but these become obliterated in the older portions. *Aristea corymbosa* reaches a height of a metre or more and has a relatively stout stem ; *Witsenia*, which is almost as tall, is much more slender. *Aristea fruticosa* differs from the others in being rather a low-growing plant which is much more freely branched.

In the two species of *Aristea* and in *Witsenia*, the basal part of the stem, on or below the ground, is much wider than the upper parts, and appears much swollen. The roots, which are all adventitious, arise from these enlarged basal parts. In *Aristea corymbosa*, roots are formed along a greater length of the stem than in any of the others. No mention is made of these enlarged stem bases in any of the systematic descriptions. The bases of the stem in the species of *Klattia* have not been seen.

Source of Material.

Aristea corymbosa was collected in Baines Kloof, Wellington. *A. fruticosa* was obtained by Professor Compton from Onrust in 1924, and I have to thank him for this, and also for supplies of material of *Aloe bainesii*, *A. dichotoma*, and of *Dracaena hookeriana* from the National Botanic Gardens at Kirstenbosch. These plants were studied for comparison. *Witsenia maura* was collected on the Cape Peninsula. Living plants of *Klattia* have not been obtainable, but I have been able to examine stems from herbarium material supplied to me by the Curator of the herbarium of the South African Museum, to whom I desire to tender my sincere thanks.

Primary Structure of the Stem.

The structure of the primary stem in all the species agrees closely with the description of Scott and Brebner * for *Aristea corymbosa*. The stem is flattened and elliptical in transverse section: the leaves are attached on the narrow edges. The vascular bundles are amphivasal; the innermost ones have a definite protoxylem, while those nearer the periphery are more regularly concentric and have no recognisable protoxylem, the tracheids forming a continuous uniform ring round the central phloem. The details of the first-formed, central bundles show a certain amount of variation. In *Witsenia* and both species of *Klattia* the protoxylem is in contiguity with the metaxylem, which forms a single row of cells round the distal side of the bundle. There is a larger amount of xylem on the proximal side. This is the type of bundle that occurs in *Dracaena*. In *Aristea fruticosa* the xylem is again continuous round the bundle, but there are two or three rows of cells on the distal side and less on the proximal. In *Aristea corymbosa*, the protoxylem is separated by parenchyma from the metaxylem. In the old stems the protoxylem becomes squashed and almost obliterated, and the appearance is of xylem on the distal side and lateral, but none on the proximal side.

The outer bundles of the primary stem are surrounded by much lignified sclerotic ground tissue, while the ground tissue in the central part is much less thickened. In these stems the central parts are formed before the outer ones. The laying down of primary bundles continues for some time, and the laying down of the outer ones and the thickening of the outer ground tissue takes place after the complete differentiation of the central portions.

As in so many monocotyledons, the primary stem shows an increase in size as the plant grows. This can easily be traced, as, on account of the sclerotic ground tissue, the amount of compression of the primary stem by the subsequently formed secondary tissues is negligible. The following measurements of the cross-section of the primary stem in *Witsenia* will illustrate this:—

	Larger diameter. mm.	Shorter diameter. mm.
Primary just complete . .	3·63	2·00
1 cm. lower	3·04	1·63
Woody stem 1 cm. below leaves .	2·04	1·26
Base of aerial stem . . .	1·80	0·99
Underground stem . . .	0·43	0·35

* Scott and Brebner, 1892

This increase of the primary stem is much less marked in the lateral branches than in the main axis.

Secondary Tissues.

Aristea corymbosa.

This is the largest of the plants. The aerial stems rise to a height of a metre or more, and attain a diameter of 12 to 20 mm. At the base the stem is either decumbent or embedded in moss growing over rocks, and in this part the diameter becomes much greater, being two to three or more times that of the aerial part. Branches are produced freely from these basal portions of the stem. In the great majority of the plants examined the aerial stem was of much less age than the lower part, and had arisen as a lateral branch on it. The upper parts are destroyed from time to time by fire or other cause, and are replaced by branches from the lower parts, which continue growth and may reach a very considerable size. As examples the following may be quoted :—

Stem A.—Undamaged, 25 cm. above ground level . diameter 12·5 mm.
5 ,, ,, ,, ,, ,, 22 ,,
Base of stem . . . ,, 34 ,,
Stem B.—Upper part replaced by lateral branches at base . . . diameter 28 to 30 mm.
Stem C.—As B. . . . ,, 49·5 mm. ×85·5 mm.
Broken base of aerial stem ,, 32 mm.

As the structure of the aerial part and of the base differ somewhat, they will be described separately.

Aerial Stem.—This was described by Scott and Brebner, and, as most of their observations have been confirmed completely, they need not be repeated in detail here. The material studied by them, however, was all of rather small stems, so that some of the very characteristic features of the plant were not shown. The cambium arises just external to the primary cylinder, and is at first a rather irregular layer, in that divisions do not take place continuously in all parts. In the main axis this cambium is not formed, and does not commence activity till the primary cylinder is complete ; indeed, there is a pause, not of great length, between the completion of the primary tissues and the commencement of secondary. In lateral branches, however, the cambium arises in the so-called formative zone, and the commencement of secondary tissues is continuous with the completion of the outer parts of the primary. In older stems the division line between primary and secondary tissues is sharp in the main axis, while in the laterals there is a gradual transition. The junction line in the main axis is undulating, as seen in transverse section.

The first-formed secondary tissue, as described by Scott and Brebner, is exceedingly compact; the bundles are in contact with one another, so that their limits cannot be exactly ascertained. Through this compact innermost zone of secondary tissue there are narrow rays of ground tissue cells that run radially. These cells are lignified and form bands of 1 to 3 cells width in cross-section. This compact zone is not very wide, though considerable variations occur. It is wider at the sides of the primary cylinder than at the ends. This feature, which was described by Scott and Brebner, is a general one; the first-formed secondary tissues are added more rapidly on the sides of the flattened stem, so that the outline becomes circular, or it may even become wider in the other direction, across what was the narrower diameter. The following are measurements, from three different stems, of the maximum extent of this innermost compact zone of secondary tissues:—

At sides of primary cylinder .	0·37 mm.	0·51 mm.	0·56 mm.
At ends of primary cylinder .	0·04 ,,	0·10 ,,	0·31 ,,

So far the structure and arrangement of the tissues exactly coincide with the descriptions given by Scott and Brebner. After the formation of the compact zone, a change takes place in the tissues formed from the cambium. Scott and Brebner say that the subsequent secondary tissue is like that formed in *Dracaena*, but this conclusion was reached by them owing to the fact that the largest stems that they examined had only a small amount of growth beyond this first compact zone. With the more extensive and often much older material that has been available in this investigation, the similarity to *Dracaena* appears to be very much less than these authors suggest.

After the completion of the innermost zone, the secondary tissues are much less compact, and the individual vascular bundles are seen separated by ground tissue. The bundles themselves occur in more or less regular concentric rings separated from each other by parenchymatous ground tissue (fig. 1). In each of these rings there may be one or more rows of bundles, separated laterally from one another by narrow straight rays of ground tissue, which are 1 to 3 cells wide in transverse section. Where more than one row of bundles is present in a ring, they are in contact along the radii of the stem. The parenchyma which separates these rings from one another is of variable width. In the earlier-formed portions, the parenchyma bands are narrower, but in older stems they become much wider and more conspicuous. They do not form very regular rings, but rather wavy bands. The rays between the bundles, which are quite straight along the radii in a ring, do not always correspond with those of the adjacent rings. In a tangential longitudinal section these rays of the ground tissue

present an appearance that is quite comparable to the medullary rays of the secondary wood of a dicotyledon. They appear as lenticular patches of parenchyma, 3 or 4 cells in width and up to 15 or 20 in depth. In the outer portions of old stems they become wider, and the similarity to a dicotyledonous ray is less striking.

The concentric arrangement in this stem is quite different from the uniform structure produced by the cambial growth in *Dracaena*, or, indeed, in any monocotyledon so far described. A discussion of the significance of these rings is deferred till after the descriptions of the other plants.

The structure also exhibits considerable differences in detail as compared

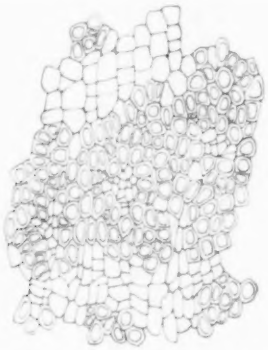


Fig. 1. *Aristea corymbosa.*—Small portion of transverse section of stem, showing ring of secondary bundles with ground tissue outside and inside. ×125.

with *Dracaena*: differences due mainly to the behaviour of the cambium cells. The early stages have been described by Scott and Brebner. At first the cambium is not a very definite zone. Vascular bundles arise from the divisions of three or four cells, not from a single one. In the older stems the cambium is a more definite layer, but is always a much narrower zone than is the case in *Dracaena*. Only the innermost parts undergo division to form the secondary vascular tissues, and of these the bundles arise from the divisions of three or more adjacent cambium cells. In the cambium zone the stages of development of the bundle are not nearly so easily followed as in *Dracaena*. The formation from several cells takes place gradually: the inner portions of a bundle may be fully formed, and the tracheids may appear displaced by sliding growth, before the cells which form the outer parts have commenced division.

On the outer side of the cambium a small amount of secondary cortical tissue is formed, and cork arises from the outermost parts. The total

thickness of the cortex and cork is always small. There is never the large production of cork that is such a feature of the arborescent Liliaceae.

Basal Part of the Stem.—In the basal part of the stem the amount of secondary tissue that is formed is much greater, and the formation continues for a much longer time. The general structure is the same as in the aerial part, but, after the completion of the compact first zone of tissue, a very much larger amount of the cells formed by the cambium remain as ground tissue. The bundles, which are arranged in concentric rings, are separated from one another by rays of much greater width, and the distance between adjacent rings is much larger. The cell walls of the ground tissue are all more or less strongly lignified, so that a hard woody mass of tissue is formed, which, with its concentric arrangement, gives a strong superficial resemblance to the wood of a dicotyledon.

The secondary bundles have the same form as in the aerial stem, and, again, are somewhat compressed laterally and extended in the radial direction. They may be close together or much separated, and, in a ring, there may be one or more rows of bundles. When more than one is present they are often in contact radially.

In addition to the concentric arrangement of the bundles, there is a certain concentric layering of the ground tissue itself. At intervals there are lines where the cells are smaller and have thicker walls. These smaller, thicker-walled cells form narrow zones of 2 to 3 cells in width. Externally they are succeeded by larger cells. These concentric zones in the ground tissue are conspicuous in a mass of tissue or under low magnifications, but when examined in detail under higher magnification are often rather difficult to trace.* The smaller cells composing them are often not much different from those around them, but the arrangement of the bundles in relation to them makes them seem more pronounced when the tissue is looked at as a mass (fig. 4). In most cases these zones correspond with the limits of vascular bundles. Very often there are a number of smaller, more closely set bundles on either side of this line. Bundles on the inner side may sometimes appear as if suddenly truncated at this line; in other cases a bundle lies right across it. These zones always occur where the bundles are close together, and never in the broad intervening rings of ground tissue.

These ground-tissue zones are less numerous than the concentric rings of bundles, a variable number of which occur between them. In most cases they are more numerous and closer together in the younger portions. The following table illustrates the relation of the rings of bundles to these zones. The numbering of these is from the cambium inwards. Two stems are taken; the first was smaller, and the measurements extend right

* *Cf.* Chamberlain, 1921.

through to the primary cylinder. The second was a very large stem, and only the outer parts were measured. The measurement of width, taken in conjunction with the number of rings of bundles, shows the increasing amounts of ground tissue that are formed in the older stems ; the size of the individual bundles changes very little.

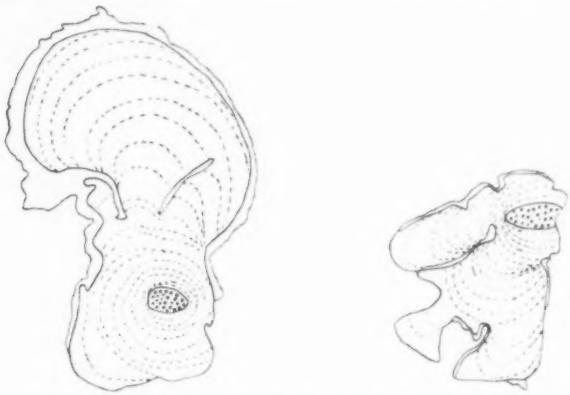
No. of zone from cambium.	Stem 1.		Stem 2.	
	No. of rings of bundles.	Width. mm.	No. of rings of bundles.	Width. mm.
1	14	4·9	5	2·36
2	3	0·82	4–5	2·12
3	4	0·88	2	0·59
4	7	2·36	3	0·64
5	7	1·95	2	0·71
6	10	2·06	3	0·94
7	3	0·47	2	0·64
8	3	0·59	3	0·77
9	2	0·53	3	1·06
10	2	0·53	4	1·12
11	2	0·53	3	0·77
12	3	0·64	3	0·59
13	2	0·34	3	0·88
14	3	0·47	7	2·60
15	Inner compact.	0·18	2	0·53

In the erect aerial portions of the stem the cambium, after its first-formed additions, divides equally all round, and, as a result, the new tissues are added symmetrically. In the basal portions, on the other hand, this is very rarely, if ever, the case. Some portions of the cambium zone grow much more rapidly than others, and the stem becomes eccentric and, indeed, often has a fluted or complicated outline (figs. 2 and 3). This irregularity of outline is due to the growth of portions of the cambium at a rapid rate, while other portions grow slowly. It is complicated and emphasised by branching ; the branches have a much larger amount of secondary growth on the outside at their base than on the inside, but these only form local bulgings.

In the older stems only portions of the tissue are living. Portions, often quite considerable, are dead and rot away after a time. Some of the old stems examined consisted solely of secondary tissues. There is no distinct region in a stem which dies first ; it is not necessarily the portions round the primary cylinder. Indeed, one stem was found in which a large portion of

the secondary tissue was dead, but the primary and one side of its secondary tissue was still active. In old stems the dead portion often extends to the surface, and the line of junction between dead and living tissues may cut right across the concentric rings of bundles. In these basal portions of the stem the cells of the ground tissue are filled with starch grains.

Branching.—In the aerial stem the branch traces depart from the ends of the elliptical primary cylinder and pass out at an angle through the outer



FIGS. 2 and 3. *Aristea corymbosa.*—Outlines of sections of basal parts of stem, showing eccentric growth from the cambium. ×3.

tissues. When secondary tissues are formed, those of the branch are continuous at the insertion with those of the main axis.

The branches from the large basal portions of the stem show some variation in their structural features. The original branches arise in the ordinary way from the primary tissues. These may become active at once, or remain as dormant buds for a variable length of time. In the former case their secondary tissues are continuous with those of the main stem. At its point of emergence the branch in most cases has an exceedingly eccentric structure with a large amount of secondary tissue on the outside and very little on the inside. Where the bud has remained dormant for a time the small primary bundles of its axis can be traced across the secondary tissues, running between the bundles, but not connected with them. When it becomes active, the secondary bundles formed connect with those of the main stem at various levels.

Branches arise frequently on thick old stems, and even on stems where the whole of the original primary and the first-formed secondary tissues have died and rotted away. Some of these arise from dormant buds, but

many of them are adventitious branches arising from and connecting with the secondary tissues alone. In structure these adventitious branches are exactly like any others.

Roots.—Scott and Brebner made a careful investigation of the roots of this plant and found they had no trace of secondary growth. This agrees with the present observations. The roots are all adventitious, and persist for a rather short time. Roots are formed in great numbers and, in the oldest stems, often arise in groups from bulging portions of the stem.

Witsenia maura.

This plant is more slender than *Aristea corymbosa*, and less branched. While the stem can attain a height of a metre or more, it is slender and cylindrical, and rarely attains a diameter of more than 7–10 mm. The base of the stem below ground is also much less bulky. There is a rapid increase in thickness to form a club-shaped termination, from the end of which the roots arise. In an undamaged stem this basal part is symmetrical and circular in outline, and reaches about 12–15 mm. in cross diameter and 1–2 cm. in length. When the aerial stem has been damaged, and subsequently been replaced by the growth of a bud, the underground portion becomes larger and more irregular in outline. The transverse diameter may reach as much as 20–25 mm. Stems of the enormous size occurring in *Aristea corymbosa* are not found in any of the other species examined.

Aerial Stem.—The cambium layer, especially in the younger portions, is a rather indefinite one, in which divisions take place rather irregularly. The secondary tissues are, in the main axis, clearly demarcated from the primary owing to the enormous thickness of the walls of the cells of the ground tissue in the latter. There are, however, generally present primary bundles which lie right across the line of junction of the primary and secondary tissues.

The first-formed secondary tissues, as in *Aristea corymbosa*, are exceedingly compact (fig. 5). The bundles are in contact with one another, so that their outlines are not traceable. The tracheids in these bundles have a small diameter and thick walls, and the amount of phloem in the bundles is very small, so that the tissue is exceedingly compact and hard. Further, there is practically no recognisable ground tissue in this portion. Owing to the sliding growth of the tracheids, any radial arrangement due to the formation from the cambium is quite obscured.

After a certain amount of this compact secondary tissue is formed a change occurs in the tissues formed by the cambium. Radially running bands of ground tissue, like medullary rays, separate the bundles. These rays are composed of cells rectangular in cross-section which have more or

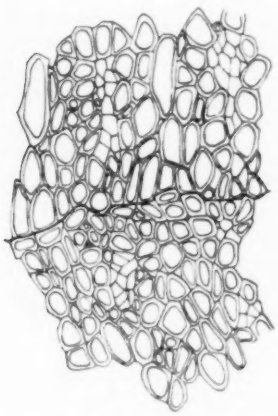


FIG. 4. *Aristea corymbosa.*—Part of section of aerial stem, showing ring in the ground tissue. The junction line has been emphasised. ×190.

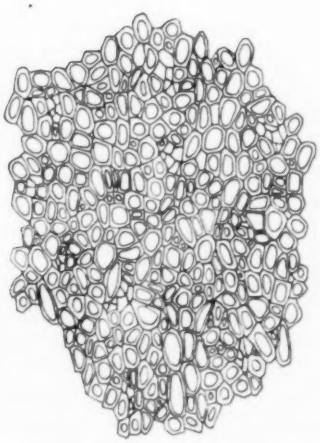


FIG. 5. *Aristea fruticosa.*—Inner part of secondary tissue, showing compact arrangement of bundles. ×180.

less lignified walls. The rays follow a remarkably straight course, as seen in transverse section, and are of exceedingly uniform thickness (fig. 6). They are 2–6 cells wide in cross-section, and 4–16 or 18 cells deep. Some are much deeper. Between these rays there is a variable thickness of tissue composed of vascular bundles (fig. 7). The bundles are in contact both radially and tangentially: in fact, the arrangement of the secondary bundles is the same as in the first-formed parts, except that the mass of tissue is separated into portions by these straight rays. These become more and more numerous as the diameter of the stem increases, so that in larger stems only a single row of bundles occurs between them.

The continued growth of the aerial stem is quite uniform in all the examples studied. The thickness of the innermost compact zone shows

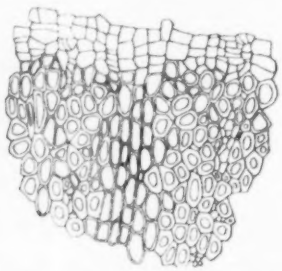


FIG. 6. *Witsenia maura.*—Outer part of old stem, showing cambium and portion of a straight ray between the bundles. ×130.

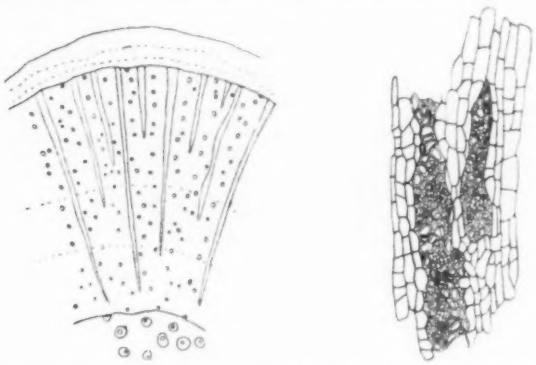
some variation. In the lower portions of the stem it is very much less than higher up. In this plant, in most cases, there is no sign of any concentric zonation in the secondary tissues. After the first change from the very compact portion to that with rays, which is gradual, the whole thickness is uniform and without any obvious breaks. In one or two stems faint indications of zones in the ground tissue occur, but these are very much less definite than in *Aristea corymbosa*, and, even in these examples where they occur, are rather indistinct and irregular. The divisions between the zones bear no relation to the bundles.

The cambium zone in *Witsenia* is much less definite than in the other plants. Very little secondary cortex is formed. In old stems the outer parts of the cortex become suberised, but no phellogen is developed, and there is no active formation of cork. The outermost cortical cells undergo a corky change before death.

Underground Stem.—As was described in the case of *Aristea corymbosa*, so here, the increase in diameter of the underground stem is brought about by an increase in the amount of ground tissue that is formed. The inner-

most portion of the secondary tissue is compact, like that of the aerial stem, though this is here a narrower zone. Beyond this, however, the bundles are separated by broad rays. Between the rays there is one line of bundles, and these are often separated by ground tissue (fig. 8). The arrangement is like that in *Dracaena* or *Aloe*, except that the rays are quite straight and regular.

The bundles themselves follow a winding course in these thick portions at the base, and in a transverse section the bundles are cut at various angles. There is a rough zonation in the bundles, due to an alternation of parts where the bundles, between the straight rays, are in contact, and parts



FIGS. 7 and 8. *Witsenia maura*.—Fig. 7. Outline of section of old aerial stem, showing rays. Positions of phloems indicated by circles. ×20.
Fig. 8. Portion of section of underground stem. ×60.

where they are separated by ground tissue. The width of these divisions varies, and, indeed, they are not always present. Stems with a diameter up to 10–12 mm. have been seen in which there is no trace of this. There is not any sign of a zonation in the ground tissue.

In the underground part of the stem the cortex is wider owing to a more rapid formation of tissue on the outside of the cambium. There is no phellogen ; the outer parts become corky.

The transition in structure, between that of the underground stem and that of the aerial, occurs quite gradually.

Roots.—The roots are all adventitious. In structure they are very much like those of *Aristea corymbosa*. They have a polyarch cylinder with wide vessels, but no secondary thickening. They arise from the cambium, and are connected with the secondary bundles of the stem. As the roots persist for some time, the base may become embedded in the secondary tissues of the stem.

Aristea fruticosa.

This is a much smaller plant with narrow, branched aerial stems that arise from an enlarged underground portion. Unfortunately, none of the material available was of plants that had not been damaged. All that has been seen had aerial shoots that had arisen from buds on the underground parts.

The structure of the aerial stem is exceedingly like that of the stem of *Witsenia*. The secondary tissues are not very sharply marked off from the primary. The innermost secondary tissues are exceedingly compact, without ground tissue and without clear separation of the bundles. The

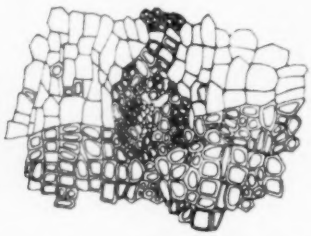


Fig. 9. *Aristea fruticosa.*—Part of section of underground stem, showing distinct ring in ground tissue. ×85.

tracheids are larger, and the number of cells composing the phloem is greater than in *Witsenia*. In the outer parts, straight radial rays separate the bundles; one or two rows occurring between. There is no indication of any concentric zonation. The structure does not bear much resemblance to that of *A. corymbosa*.

The cambium is not very regular; secondary cortex is formed in old stems, and externally cork is formed from a phellogen.

The structure of the underground stem is also very much like that of *Witsenia*. The bundles are separated by large straight rays of ground tissue. Between the rays they are also usually separated by several rows of cells. In the underground stem the structure is continuous throughout; there is none of the compact inner secondary tissue. The thick fibrous cells of the periphery of the primary cylinder are also absent.

In some cases there is some sign of zonation in the ground tissue in the underground stem. This is all lignified, but lines occur where there is a sudden change in the size and thickness of the cells (fig. 9). In no case has more than one, or at most two, of these lines been observed in a stem, even in those of considerable size. These lines would appear to represent the position of the cambium at a time when the upper portions were destroyed

by fire or other cause, rather than a normal growth phenomenon. This is suggested by the fact that they are so infrequent and that in some cases the bundles that abut on these lines appear incomplete.

The structure and arrangement of the roots is like that of *Witsenia*. There is no cambium or secondary growth. The large vessels that occur in the roots of the two species previously described are absent in this plant.

Klattia.

A limited supply of both species, *Klattia partita* and *K. stokoei*, has bee examined. The two show certain differences in detail. In neither case have the underground or basal portions of the plant been seen.

Klattia stokoei.—In the single stem examined there is not a very sharp line of demarcation between the primary and secondary tissues. The secondary tissues are very uniform. The bundles are in contact with one another in radial rows, separated, right into the primary cylinder, by rays of ground tissue, 1–4 cells across, the cells of which are lignified. Between these rays are one, or occasionally two, rows of bundles. The specimen had secondary tissues 0·9 mm. in thickness which were quite uniform. The cambium was a narrow, not very regular, zone. No cork formation had yet occurred.

Klattia partita.—Material from two plants was examined of this species. The secondary tissues were sharply marked off from the primary, the outer portions of which were very much thickened. The secondary tissues in one stem, collected on the Helderberg, showed a distinct concentric zonation. The innermost portions were very dense and compact without ground tissue or any clear radial arrangement ; beyond this was a zone where the bundles were separated by rays of lignified ground-tissue cells. The third zone, which extended to the cambium, had wider rays. Each zone was clearly marked off from the adjacent one by a single row of ground-tissue cells which formed a concentric ring. What has been termed the third zone had a structure rather like that of portions of the stem of *Aristea corymbosa* ; the bundles in it were separated by ground tissue which formed irregular wavy concentric lines. The total thickness of secondary tissues was 1·50 mm., of which the compact zone measured 0·16 mm., the second 0·64 mm., and the outermost, which was subdivisible into three, 0·74 mm. No cork had been formed in this stem.

In the other specimen, from material collected at Grootvadersbosch, secondary tissues to a thickness of 1·2 mm. had been formed. The whole of this was uniform, compact, and very hard, like that of the innermost portion of the first specimen. Without further examination of larger supplies of material, it is not possible to venture an explanation of the differences between these plants.

General Discussion.

These five plants, which have been examined, exhibit many features in common, though in detail they show considerable variations. Their common features are largely those which distinguish them from the other monocotyledons with secondary growth. While the general plan by which the secondary tissues are formed is the same as in the Liliaceae and others, namely, an extra-fascicular cambium, from which are formed complete vascular bundles, the details of formation are quite different. In all these plants the cambium forms a zone in which divisions do not take place very regularly. A cell of the cambium undergoes division for a time and then ceases to do so. Again, in the older stems, only the innermost portions of the zone undergo divisions to form secondary tissues. There is not in any of the plants any sign of cells in the outer or middle portions of the cambium zone undergoing divisions to form vascular bundles, which forms so characteristic a feature of *Dracaena*, *Aloe*, and others. In the latter the developmental history of the vascular bundle from the cambium is much more readily studied than can be done in those described in the present account. The formation of bundles from the innermost parts of the cambium alone, and their origin from three or more cells, instead of from the divisions of a single one, result in a much more regular tissue than occurs in *Dracaena*, for example. There is much less sign of strain or displacement due to the unequal degree of enlargement of the cells. A comparison of a section of the secondary stem of *Witsenia*, with its extremely regular and straight rays of ground tissue, with one of *Dracaena*, in which the ground tissue forms undulating lines that are markedly displaced by the bundles, brings out this feature very clearly.

This formation of the bundles from several cells, and the somewhat intermittent divisions of the cambium cells, result in the very much more compact secondary tissue that is the first formed in all these plants, with the exception of *Klattia stokoei*. As the diameter of the stem increases, the cells that divide to form the bundles become separated, and rays of ground tissue are laid down between. This is especially well seen in *Witsenia*, where the number of these rays increases with the increase in diameter of the stem. In the case of *Klattia stokoei*, where these rays occur all through the secondary tissue, the same relation may apply, as this plant has a larger and more massive primary stem than any of the others.

Growth Zones.—The regular concentric structure which occurs in *Aristea corymbosa* and in one example of *Klattia partita* is a peculiar feature, and one quite distinct from what occurs in the arborescent monocotyledons so far described. Growth zones in a monocotyledon stem have been described by Chamberlain * in the stem of *Aloe ferox*. In this plant, zones

* Chamberlain, 1921.

in the ground tissue occur, but they are not very distinct. Very much more obvious zones occur in the large *Aloe bainesii*, where they are sharply marked by changes in the size and thickness of the cells of the ground tissue. The secondary tissue in this plant is made up of alternating bands which have the ground-tissue cells with thin walls, and bands where the cells are smaller and have lignified walls. The bundles in the thin-walled portions are somewhat larger than those in the thicker-walled parts. Apart from these features, the structure of the secondary tissues is exactly like that of *Dracaena*. The general distribution of the bundles is uniform, as in that plant, and does not show any regular concentric arrangement. In these species of *Aloe* these zones certainly appear to correspond to the seasonal changes of moisture in the surroundings, and the very much more definite appearances seen in *Aloe bainesii* can be correlated with the more marked cycle of climatic conditions existing in its habitat.

In *Aristea corymbosa* there occurs a double system of concentric rings, namely, the rings of vascular bundles and the less frequent or less regular concentric zones in the ground tissue. The latter, the zones of ground tissue, are in their features much the most readily comparable with the growth zones in *Aloe*. But, as has been pointed out above, these are not regular, and in some cases are very inconspicuous, or even absent over considerable portions.

Some study has been made of the condition of the cambium and the tissue formed from it at different seasons. Material of *Aristea corymbosa* has been collected in March, May, and July. In March, which is before the winter rains commence, the bundles nearest to the cambium were completed, and the appearance suggests the formation of a ring of ground tissue. That collected in May showed partly formed bundles at the cambium, while in the July material there was evidence of active formation of bundles.

From the above it seems justifiable to conclude that the intervals of ground tissue between the rings of bundles correspond to the seasonal rest period in the dry portion of the year. As was noted earlier, there may be one or more rings of bundles between these divisions.

The much less regular rings in the ground tissue probably correspond to periods of adverse conditions, due to drought or other cause. Their lack of regularity, and especially their greater frequency in the younger portion, lend support to this hypothesis. *Aristea corymbosa*, which lives by streams and in moist protected situations, is not subjected to such a regular sequence of severe drought periods as occur, for example, in the habitat of *Aloe bainesii*. The occasional occurrence of these zones in the ground tissue of other plants can be explained on the same basis. As was stated, one or two occur sometimes in the underground stem of *Aristea fruticosa*. Here

they were regarded as representing damage, by fire or otherwise, to the aerial parts. Their occasional occurrence in *Witsenia*, where they are indistinct, may be correlated with habitat. This plant inhabits peaty swamps where, as a rule, the seasonal fluctuations of moisture will be less marked. In most of the specimens of this plant these rings are quite absent. The rather peculiar zonation in *Klattia partita* cannot be explained without a much more thorough examination of living material.

Relationships.—These plants have such a striking similarity of habit and of structure, and are so distinct in these features from the majority of the Iridaceae, that it seemed advisable to make some study of the plants nearly allied to them.

Witsenia is a monotypic genus, and *Klattia* comprises only the two species described. On the other hand, *Aristea* is a genus including about thirty species, occurring in south and tropical Africa. Not one of these, however, has a habit at all like the two described. The plants are small, with basal leaves arising from a thin, partly underground stem, or from an enlarged creeping rhizome. Of species with the first type of stem, *A. cyanea*, *A. juncifolia*, and *A. dichotoma* have been examined. In all these the structure is practically the same: the basal part of the stem has a central cylinder containing numerous amphivasal bundles, often closely crowded towards the periphery. This cylinder is bounded by a definite endodermal layer, the cells of which have the radial and inner walls very much thickened. There is no sign of any cambium or of any kind of secondary increase in thickness.

The species with large rhizomes, of which *A. capitata* and *A. spiralis* have been examined, show the ordinary structure that occurs in many other monocotyledonous rhizomes, with no trace of secondary growth.

None of the other species of *Aristea* that have been seen growing or in herbaria show any indication of secondary growth. The great contrast that exists in habit between the two woody species that have been described here, and all the others in the genus, is so striking that they are often placed in a separate genus, *Nivenia*, though the differences in floral characters are small. This is done in Engler and Prantl,* and by Marloth,† to quote only two examples. On the other side, the similarities have led some to unite all these plants, including all the species of *Aristea*, under one genus.‡

While there is at present no final agreement as to the details of the classification of the Iridaceae, the five plants that are here considered have always been grouped together. The schemes of classification of Bentham and Hooker,§ and of Engler and Prantl,‖ show many differences,

* Pax, 1888.
† Marloth, 1915.
‡ Von Post and Kuntze, 1904.
§ Bentham and Hooker, 1880.
‖ Pax, 1888.

but agree in this, and in associating with these plants the genus *Cleanthe*. *Cleanthe* is a Cape genus comprising the single species *C. bicolor*, which is a plant with a short underground rhizome which has no appearance of possessing secondary growth, though no material has been available for detailed examination.

As regards their structure, these five species appear quite isolated at present in the family, and do not seem to be connected by any forms that show any kind of intermediate condition. The similarity to the arborescent Liliaceae and others, in the method of formation of the secondary tissues, is, perhaps, best looked upon as a case of parallel development.

However tempting it may be to enter into speculations on the possible origin of these plants, or of secondary growth among the monocotyledons, it does not seem that any useful purpose is to be served by an elaboration of the very meagre evidence available in the present state of our knowledge. Nor is it part of our purpose, at present, to enter into a discussion of the position of these plants in the Iridaceae or in the Cape flora. Marloth * and others regard these plants as being exceedingly ancient, and as possibly representing relics in this flora of previous conditions. Their habitat, restricted to stream sides and marshes, might be taken as corroborative evidence for this view.† On the other hand, the very limited distribution, and the closely allied genera with few species, might be held as supporting a recent origin. On the whole, without entering into a long discussion of the various lines of evidence that can be brought forward, it seems advisable to leave the question a quite open one.

Summary.

1. Five species of the Iridaceae have woody stems with secondary growth, the structure of which is described. All have a very similar habit, with linear distichous leaves.

2. The primary stem is elliptical in section. The cambium arises external to the primary cylinder.

3. The bundles formed from the cambium arise from three or more cells. Only the innermost part of the cambium zone divides to form secondary vascular tissues.

4. In all the species, except *Klattia stokoei*, the first-formed secondary tissues are very compact, with the bundles in contact with one another, and with very little or no ground tissue.

5. In *Aristea corymbosa* the subsequent secondary tissues are laid down in concentric rings consisting of one or more rows of bundles separated by ground tissue.

* Marloth, 1908. † *Cf.* Bews, 1925.

6. At the base of the stem in this species the rings and the bundles are more separated. Growth of the cambium is not even, and irregular-shaped stems result.

7. In the ground tissue, especially at the base, there are concentric rings marked by differences in the thickness of the cell walls.

8. Evidence is brought forward to support the view that the concentric rings of bundles correspond to the seasonal activity of the cambium, and that the zones in the ground tissue are correlated with periods of drought, etc.

9. In *Witsenia maura* there is no concentric structure. After the first-formed compact tissue, the bundles are separated by straight radial rays of ground tissue. These increase in number as the size of the stem increases.

10. The swollen underground portion of the stem has the same structure, but the rays are wider and more numerous.

11. *Aristea fruticosa* agrees in all essential points with *Witsenia*.

12. *Klattia stokoei* has secondary tissues that, from the commencement, have a structure like that in the later-formed parts of *Witsenia*.

13. *K. partita* has a definite concentric arrangement.

14. In all the plants the roots are adventitious, and in old stems arise from the cambium. There is no secondary growth in the roots.

15. None of the other species of *Aristea* nor of allied genera have any secondary growth.

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Fig. 1.

Fig. 2.

Fig. 3.

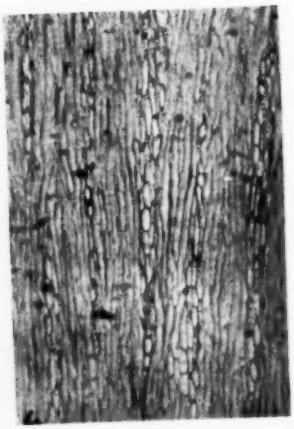

Fig. 4.

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DESCRIPTION OF PLATE.

Aristea corymbosa.

Fig. 1. Basal parts of two old stems. Some of the lateral branches have been removed. $\times \frac{1}{12}$.

Fig. 2. Cross-sectional view of an old stem, showing concentric rings. The greater part of the tissue here is dead. Only the top (paler) part is active. $\times \frac{3}{4}$.

Fig. 3. Part of a transverse section of the basal part of stem, showing concentric arrangement of the bundles and a division zone in the ground tissue. ×48.

Fig. 4. Longitudinal tangential section of aerial stem, showing parenchyma of the rays and the irregular course of the tracheids. ×65.

AN EXTENSION OF CEVA'S THEOREM TO POLYGONS OF ANY NUMBER OF SIDES.

By Alexander Brown.

1. Ceva's Theorem states that the product of the three ratios into which concurrent lines through the vertices of a triangle cut the opposite sides is equal to unity. For a polygon with an odd number of sides a similar result can be got connecting the ratios of the segments into which concurrent lines through the vertices cut the sides *opposite* to them. A more comprehensive result is obtained below, valid for polygons of even or of odd number of sides which includes the above as particular cases and also leads to some other results apparently new.

2. Consider a polygon of n sides whose vertices in clockwise order are $A_1, A_2 \ldots A_n$. Let O be any point in the plane of the polygon. The lines A_rO are produced to cut the sides, $n-2$ in number, which do not meet at A_r. The point in which A_rO cuts the side A_{r+s}, A_{r+s+1} is called $P_{r,s}$, so that the s here indicates the number of vertices that are encountered in passing along the perimeter clockwise from A_r to the side on which P_{rs} lies.

Then if

$$K_s = \prod_{r=1}^{n} \frac{A_{r+s} P_{r,s}}{A_{r+s+1} P_{r,s}}$$

the proposition to be proved is

$$K_s \cdot K_{n-s-1} = 1 \text{ for any value of } s.$$

For the proof first obtain K_s in terms of sines of angles. Thus :

$$K_s = \prod_{r=1}^{n} \frac{OA_{r+s} \cdot \sin A_{r+s} O P_{r,s}}{OA_{r+s+1} \cdot \sin A_{r+s+1} O P_{r,s}}$$

$$= \prod_{r=1}^{n} \frac{\sin A_{r+s} O P_{rs}}{\sin A_{r+s+1} O P_{rs}} \quad \ldots \quad (1)$$

Now the points $A_\alpha O P_{\alpha,\beta}$ lie on a straight line, and so do the points $A_\gamma O P_{\gamma\delta}$ where $\alpha, \beta, \gamma, \delta$ have any values; it follows that the angles

$A_\alpha O P_{\gamma\delta}$ and $A_\gamma O P_{\alpha\beta}$ are either equal or supplementary and so have their sines equal; hence in the equation (1) we may interchange the suffix of A with the first suffix of P and take the second suffix of P to be any number we choose.

Two typical consecutive terms in (1) are

$$\ldots \frac{\sin A_{r+s} O P_{r,\ s}}{\sin A_{r+s+1} O P_{r,\ s}} \cdot \frac{\sin A_{r+s+1} O P_{r+1,\ s}}{\sin A_{r+s+2} O P_{r+1,\ s}} \ldots$$

and these can be replaced by

$$\ldots \frac{\sin A_r O P_{r+s,\ \kappa}}{\sin A_r O P_{r+s+1,\ \lambda}} \cdot \frac{\sin A_{r+1} O P_{r+s+1,\ \mu}}{\sin A_{r+1} O P_{r+s+2,\ \nu}} \ldots$$

or rearranging

$$\ldots \frac{\sin A_r O P_{r+s,\ \kappa}}{\sin A_r O P_{r+s+1,\ \lambda}} \cdot \frac{\sin A_{r+1} O P_{r+s+1,\ \mu}}{\sin A_{r+1} O P_{r+s+2,\ \nu}} \cdot \ldots \quad (2)$$

Now the middle term in (2) will lead to a ratio of segments of sides if the points $P_{r+s+1,\ \lambda}$ and $P_{r+s+1,\ \mu}$ lie on the side $A_r A_{r+1}$.

To secure this

$$\lambda = \mu$$

and

$$r+s+1+\lambda = r,$$

i.e.

$$\lambda = \mu = -s-1 \quad \ldots \quad (3)$$

(Note that any suffix can have any multiple of n added to it thus, *e.g.*

$$A_{n+2} = A_2,\ P_{n+r,\ 2n+s} \text{ is } P_{rs}.)$$

Equation (3) can be written

$$\lambda = \mu = n-s-1 \quad \ldots \quad (4)$$

With this substitution the middle term in (2) becomes

$$\ldots \frac{\sin A_{r+1} O P_{r+s+1,\ n-s-1}}{\sin A_r O P_{r+s+1,\ n-s-1}} \ldots \quad (5)$$

The first numerator and the last denominator of (2) may be written together as

$$\frac{\sin A_1 O P_{1+s,\ n-s-1}}{\sin A_n O P_{n+s+1,\ n-s-1}},$$

which is the same as

$$\frac{\sin A_{n+1} O P_{1+s,\ n-s-1}}{\sin A_n O P_{1+s,\ n-s-1}}.$$

Hence the continued product of which (5) is a typical term is

$$\prod_{r=1}^{n} \frac{\sin A_{r+1} O P_{r+s+1,\ n-s-1}}{\sin A_r O P_{r+s+1,\ n-s-1}},$$

which is

$$\frac{1}{K_{n-s-1}}.$$

Hence

$$K_s . K_{n-s-1} = 1 \quad . \quad . \quad . \quad . \quad . \quad (6)$$

3. Some special cases may be noted.

(*a*) If n is odd, equal to $2m+1$, we get on putting $s=m$

$$K_m . K_m = 1$$

i.e.

$$K_m = \pm 1 \quad . \quad . \quad . \quad . \quad . \quad (7)$$

i.e. the product of the ratios of the segments into which concurrent lines through the vertices of an odd-sided polygon cut the opposite sides is equal to unity.

(*b*) Write down all the possible equations in (6) and multiply together, remembering that s cannot have the values O or $n-1$; we get on extracting the square root

$$K_1 . K_2 . \ . \ . K_{n-2} = \pm 1 \quad . \quad . \quad . \quad . \quad (8)$$

i.e. the combined product of the ratios of segments into which the sides of any polygon are divided by concurrent lines through all the vertices is equal to unity.

(*c*) For a triangle we get Ceva's theorem.

For a quadrilateral we get $K_1 K_2 = 1$, which may be also considered a special case of (8).

For a pentagon, $K_1 K_3 = 1$ and $K_2 = 1$.

For a hexagon, $K_1 K_4 = 1$ and $K_2 K_3 = 1$.

For a polygon of $2n$ sides we get $(n-1)$ relations.

For a polygon of $(2n+1)$ sides we get n relations of which one is of type (7).

(*d*) If the symbol K^s be used for the product obtained exactly in the way in which K_s was obtained, but with counterclockwise sense of description instead of clockwise, K^s is the same as K_{n-s-1}, and the proposition (6) can be written $K_s = K^s$.

The results (*a*) and (*b*) above are obtained by A. C. Aitken in Mathematical Notes, No. 22, May 1924.

A STATISTICAL INQUIRY INTO THE POPULATION PROBLEM IN SOUTH AFRICA.

By Alex. Roberts.

(With one Chart.)

I would venture in the present paper to deal in a somewhat rigorous manner with such population data as most men will regard as trustworthy, with a view to the ascertainment of the numerical factors which enter into the mathematical expressions for the magnitude of the population at any date, as well as to correct some common misapprehensions with regard to the relative growth of the several races in South Africa. In the latter direction I shall confine myself severely to a comparison of two races, the White people and the Bantu people.

The peculiar racial circumstances of the country, the importance of such an inquiry in its relation to social and economic legislation, should serve to render the inquiry of supreme interest to thoughtful men.

I shall attempt to deal with the investigation in this order :

(1) An exposition of the mathematical setting of the problem. I shall endeavour to make this as complete as possible.

(2) An examination of the rate of increase of the white population in the Cape Colony, defining this area to mean its present geographical limitations.

(3) A similar investigation with regard to the population of Natal, again regarding Natal as the region at present defined as such.

(4) An investigation of the same nature with regard to the Orange Free State.

(5) An investigation regarding the white population of the Transvaal.

(6) A similar investigation with regard to the total population of the Union.

(7) A consideration of the available statistics regarding the native population of the Union.

(8) Certain conclusions depending on the foregoing.

It is hoped that under these heads this important problem will be reasonably and adequately considered.

(1) Mathematical Statement.

When economic, climatic, and health conditions bearing on national life are constant in their operation and uniform in their degree and quality, then the population of a country increases in a very definite geometric ratio, expressed by the equation :

(1) . . . . . $a_1 = a_0 r^n$

where

a_0 = population at a definite epoch, say 1900.
r = rate of increase per unit per year.
n = number of years before or after the epoch.
and a_1 = population at any required date.

It is evident, however, that the conditions of national life are not always constant and uniform. Fortunately, few countries are in that state of deadly uniformity. Nearly all over the world conditions, political and social, are in a state of flux. Famine, war, pestilence, plague, periods of luxury, years of poverty, sweep over the land, and the population in consonance with these changing conditions undulates, now under the mean, now over. But these aspects of change are less permanent than is usually believed. Nature restores itself with extraordinary rapidity. Its convalescence from a period of depression, or its decline after a time of national exaltation, is followed by an impulse in the other direction, and after a series of ups and downs in national progress matters quickly revert to the mean order of things. We may regard such temporary variations as waves on the surface of a deep sea. Underneath are the permanent and stable conditions of national life and growth.

But there are vast secular changes in the stream of population just as there are secular changes in climate, in the form and elevation of our sea shores. It is difficult to determine what are the causes of these secular changes. Efforts have been made to trace them to profound changes in national life and character, due to long-sustained economic and political stress and strain. But these investigations have not led us far. They have the same vagueness of result as similar investigations dealing with the numerical relation of the two sexes.

That secular change in the rate of increase of population does exist there can be no doubt. Reliable statistics carried on, for over a century, in France, in Spain, in Germany, in England, undubitably prove this.

Granting that a secular change in the rate of increase may occur, equation (1) will accordingly have to be modified to include this secular change.

If the change in rate is a constantly increasing or decreasing quantity, then the introduction of a factor depending on the square of the time will

usually be sufficient to interpret the systematic change in rate. Higher powers than the second will only be necessary when the records are both very reliable and also extend over a long period. We may, therefore, when there is a progressive change in rate, of the nature of an arithmetical progression express equation (1) thus :

$$(2) \quad . \quad . \quad . \quad . \quad . \quad a_1 = a_0 r^n k n^2$$

where k is greater than unity when the rate is uniformly increasing, and less than unity when the rate is uniformly decreasing, as it has been in every province in South Africa, with regard to European population, since 1910.

For purposes of computation, equation (2) may be expressed :

$$(3) \quad . \quad . \quad . \quad \log a_1 = \log a_0 + n \log r + n^2 \log k.$$

The expression

$$a_1 = a_0 r^n k n^2$$

furnishes an expression, also, for the determination of the date when, with a declining rate, the population will no longer increase. It will then for a time become more or less stationary.

The presumption underlying this mathematical treatment is that the same forces and circumstances which have governed the growth of the population in the past will continue doing so, not infrequently a very unsound assumption, for while population like all other natural phenomena must depend upon certain definite if obscure laws, our knowledge of these is so indefinite, we know so little of their actions and interactions, that our numerical investigations must be almost entirely empirical.

Consider the fundamental equation :

$$a_1 = a_0 r^n k n^2,$$

that is

$$\log a_1 = \log a_0 + n \log r + n^2 \log k ;$$

differentiating with respect to n and equating to zero we have

$$0 = \log r + 2n \log k.$$

When $\log k$ is a positive quantity, a condition which exists in only one instance in South Africa, then there is no point at which the population ceases to increase.

When $\log k$ is a negative quantity

$$2n \log k = \log r,$$

$$\text{or} \quad 2n = \frac{\log r}{\log k}.$$

A solution of this equation gives the instant when the population passes from an increasing to a decreasing quantity.

This is the form in which I have applied the expression to such populations as, from their conformity to theory, seemed to me to warrant my using it as a basis of prophecy.

I have not introduced any terms into the preceding equation

$$a_1 = a_0 r^n k n^2$$

which would interpret a *per saltum* change in population such as the ravages of disease, loss by war, or deaths through famine, might be expected to produce, for I hold that such disasters are less marked, and certainly less lasting in their effects, than most people would be willing to allow.

If modern thought has set itself against the idea that Nature abhors a vacuum, it has accepted as a truism the principle that Nature abhors violent change. It is conservative in all its moods and actions.

The population of certain countries exhibits a cyclical change. I hope to be able to prove that such a periodic change affects the population rate in Natal, and still more so in the Cape Colony. In the latter instance we have more or less reliable data stretching over a period of two hundred years: a long period truly, but not too spacious in which to discover and to describe such an elusive and long-period variation as a cyclical change in the increase or decrease of population must be.

A secular variation, that just dealt with, where the progress or otherwise of the population may be expressed by

$$a_1 = a_0 r^n k n^2$$

is much more easy to determine. The dominating factor is that of time.

In a periodic or cyclical variation of rate, another factor enters into the equation which describes the theoretical population at any date. The expression takes a trigonometrical or periodic form, returning to itself after the lapse of decades or even centuries. The variation in rate is completed in a given time called the period of variation; and the margin, marking the wanderings on either side of the mean rate, is the amplitude of the curve.

It is possible that many secular variations are in reality periodic in character.

It is very difficult to understand what can be the cause of such variation: what deep-seated forces or conditions go to produce these population tides, the ebb and flow of nations.

But we are equally in ignorance of the cause of many of Nature's physical cycles—magnetic variation, climatic variation, stellar variation. These vagations seem to be part of a vast rhythmic movement reaching out to the furthest star, and endowing this universe of ours with an endless interest.

This cyclical variation in population may be set forth in the expression :

(4) . . . . . $a_1 = a_0 r^n k^{\cos(n\theta - M)}$,

or, adapting this for logarithmic computation,

(5) . . $\log a_1 = \log a_0 + n \log r + \log k\{\cos(n\theta - M)\}$.

The angle θ measures the length in years of the cycle, and the angle M indicates the maxima and minima points on the curve.

The duration, d, of the cycle of variation is determined by the equation

(6) . . . . . $d = \frac{360^\circ}{\theta}$

and the maxima and minima of the curve by

(7) . . . Max. when $n\theta - M = \pm 360^\circ$

(8) . . . Min. when $n\theta - M = \pm 180^\circ$.

The similarity between expressions (2) and (4) will be evident even to a casual student.

The relationship lies in this that when a rate change is secular in duration it is only a circular change with an infinite radius, or at least one beyond the means of the data to define.

This portion of this investigation seems the most suitable place to call attention to a mode of determining rates of increase, and, therefore, comparison of rates, which is both inaccurate and misleading.

It is too often forgotten that population increase or decrease is upon a geometric, not upon an arithmetical, basis. Its fundamental principle is compound interest, not simple interest.

If we have two values a_1 and a_0 separated by a difference d, in an interval n, then the simple arithmetical determination of rate, and the one usually employed, is :

(9) . . . . . $r = \left(1 + \frac{1}{n} \cdot \frac{d}{a_0}\right)$.

But population does not increase or decrease according to an arithmetical progression : it moves upwards or downwards along a geometrical progression. Now the expression for the rate under this consideration is :

$$r = \sqrt[n]{\frac{a_1}{a_0}} = \sqrt[n]{1 + \frac{d}{a_0}}.$$

Expanding this latter expression we have :

(10) . $r = 1 + \frac{1}{n} \cdot \frac{d}{a_0} + \frac{(1-n)}{2n^2}\left(\frac{d}{a_0}\right)^2 \ldots$

Since n must always be greater than unity, the expression in (9) will give a greater value for the rate of increase than the expression (10) by the amount

$$(11) \quad . \quad -\left(\frac{(1-n)}{2n^2}\left(\frac{d}{a_0}\right)^2+\frac{(1-n)(1-2n)}{6n^3}\left(\frac{d}{a_0}\right)^3 \ldots\right)$$

It will be at once evident that the significance of this expression depends upon n, the interval between the two values compared and the amount of the difference, d, between the values.

When $n=1$, expressure (11) disappears and equation (9) is the same as equation (10); but the instant we leave unity as the value of n, this equality disappears and the disparity grows the further we are removed from unity.

A simple instance will exemplify this. It is taken, slightly altered, from an example in a census volume. Three dates and populations are compared:

1900=1000 population.
1905=1100 ,,
1925=1600 ,,

Now in the arithmetical method employed in the census, it was reasoned thus: an increase of 100 in five years on a population of 1000 gives an increase of 2 per cent.,

$\therefore$ 1900–1905=increase 2 per cent.;

an increase of 500 in twenty years on a population of 1100 gives an increasing rate of 2·3 per cent.,

$\therefore$ 1905–1925=increase 2·3 per cent.

If, however, we go straight from 1900 to 1925, with an increase of 600 in twenty-five years, the annual increase is

1900–1925=increase 2·4 per cent.

These figures heartened the computor into the belief that all was well, that there were distinct evidences of improvement.

But what are the actual conditions when worked out on a geometric basis:

1900–1905=increase 1·93 per cent.
1905–1925= ,, 1·90 ,,
1900–1925= ,, 1·91 ,,

Instead, therefore, of the population going forward it is actually going back.

When the comparison is not instituted for similar intervals, or for the same interval for different countries, there is apt to creep in wrong con-

clusions unless our comparison is based upon a rigorous geometric progression.

I offer this criticism in all diffidence to those men to whom we owe so much for the inexhaustible patience, the weariless work, the comprehensive outlook, the national spirit they have put into the work of each census, and, most of all, into the census of 1921.

(2) Statistics of the White Population in the Cape Colony.

In the 1865 Cape Census Report the following statement is made (Introduction, p. iii) :—

> "No census in the proper acceptance of the term has been taken of the Colony before the present occasion."

To a certain extent this is true. Subsequent to 1865 the various enumerations were made on a more or less scientific basis, and the figures submitted by the directors are worthy of respect. Yet diligent inquiry and careful consideration will reveal data prior to 1865 not unworthy of acceptance as material for a comprehensive investigation into the matter of population.

In the exceedingly able Census Report for 1891 there is given a most valuable series of early enumerations (Introduction, p. ii).

Then there are the figures given by Theal in various chapters of his History. Those who know Theal's love of accuracy will readily accept these numbers.

From time to time reports on the population statistics were sent to the British Government by the colonial authorities. Such a report was sent in 1806, and again in 1849. In this latter enumeration there was no distinction made in the Cape Town district between white and coloured. A census of Cape Town alone, made in 1824, gives the following figures (S.A. Commercial Advertiser, 3rd March 1824) :—

White inhabitants . . .	8246
Free blacks	1870
Prize slaves	656
Hottentots	520
Slaves	7076=18,368

A comparison instituted between this and later enumerations makes it possible to arrive at an approximate division between the white and coloured population of Cape Town in 1849.

It may come as a surprise to those who exclaim against the apparent increase in these days of coloured people in the Cape Town streets that a century ago the population of the colonial capital was equally divided between coloured and white, and that if we go still further back the prepon-

derance is on the side of the coloured man. During the past century and a half the ratio between coloured inhabitants and white inhabitants has been slowly decreasing. The census enumeration for 1921, nearly a century later than the date just dealt with, gives the following figures for Cape Town :—

European	113,300
Coloured	87,000
Native	4,700
Asiatic	2,400

This divergence from the main argument of the present paper is submitted here in the hope that it may serve to correct a statement one hears so frequently, that Cape Town is overrun by coloured folk. It is an untrue statement ; and, like many such, creates a distinct mental attitude towards economic and political questions.

The various official enumerations are stated in the Year-Book of the Union of South Africa, and need not be repeated here. The curious will find information concerning this and also concerning related matters in the Official Year-Book, No. 6, pp. 132–164.

Newspapers, reports, blue books, afford a very mine to the diligent student ; I have as far as time and opportunity have served me sought to make use of this material. In no uncertain way this browsing into past records, while affording no meagre pleasure to myself personally, has corrected or supported the figures given in the following table. I would ask readers who do me the honour to read this paper, to believe that I have done everything possible, wandered into many byways, to make the submitted data as exact and final as diligent research could make them.

It would burden the present paper to state the authorities, the material that have been consulted and used to check statements. Above all would it burden the paper to indicate the steps that have been taken to reduce the figures to a uniform géographical area.

In 1865 Kaffraria was annexed to the Cape ; in 1871 the Diamond Fields ; in 1890 Griqualand West ; in 1894 Pondoland ; and in 1895 British Bechuanaland. It is evident that figures taken in 1865 are not comparable with those taken in 1895, and still less with those taken in 1925. The greatest care, however, has been exercised in reducing all numerical data to a common geographical area. This reduction formed not the least difficult matter in the present investigation, and no doubt future research may modify the figures thus obtained, but I am convinced that the rectification will have no influence on the general issues to which the figures I have accepted give rise.

In stating the figures from 1700 to 1800 many questions arise. There

was certainly in the very early days of the Cape Colony not such a distinctive line of colour between the races as there is to-day. Diaries, letters, and journals of those delightful old-world days prove that colour was not always a bar. There are records of coloured men, and of coloured women, being received at Government House. Now I am not dealing with the South African political aspect of the question. It is the numerical statement which is under examination.

And one has grave doubt whether the returns under Europeans, a hundred and fifty years ago, were just what the designation described them to be.

Into the figures I have included those enumerated as officials. Many of these, soon after the taking over of the Cape of Good Hope by the Dutch, remained in the country, remained to give to future generations that severe cast of thought, that high courage, that religious fervour, which we for ever associate with the soldiers revealed to us in Motley's Dutch Republic.

It may be of interest to give the definite figures which I have selected for my investigation into the changes operating in the white population of the Cape Colony.

The following series gives these : the headings explain themselves.

European Population of the Cape Colony at Various Dates.

No.	Year.	*n.*	Chief authority.	Population.
1	1672	—228	Old Records.	600
2	1690	210	Census Report, 1891, p. ii.	1,330
3	1705	195	,, ,,	2,110
4	1744	156	,, ,,	5,150
5	1765	135	,, ,,	8,630
6	1770	130	,, ,,	9,000
7	1775	125	,, ,,	11,000
8	1791	109	Theal's History.	16,000
9	1806	94	Report to British House of Commons.	26,000
10	1820	80	Theal's History.	42,200
11	1849	51	Report to British House of Commons.	93,000
12	1856	44	Census Report, 1865.	119,000
13	1865	35	,, ,,	192,000
14	1875	25	,, 1875.	241,000
15	1891	— 9	,, 1891	380,000
16	1901	+ 1	Estimate by Cape Government.	517,000
17	1904	4	Census Report, 1904.	580,000
18	1911	11	,, 1911.	582,000
19	1918	18	,, 1918.	619,000
20	1921	+ 21	,, 1921.	650,000

The numbers in the preceding table are given to three significant figures only; a striving after greater accuracy would not materially, if at all, affect the results.

I have not weighted the various data. If future students of the problem deem this desirable, then the official census figures ought to have treble the weight of those not so obtained.

To ascertain the numerical elements determining the growth or variability of the population as recorded in the preceding table, we shall solve the necessary equations by using the simple expression:

$$(1) \quad . \quad . \quad . \quad . \quad . \quad a_1 = a_0 r^n$$

$$\text{or } \log a_1 = \log a_0 + n \log r$$

where $\log a_0$ and $\log r$ are unknown: $n=(t-1900)$.

A solution of the nineteen equations of condition gives:

$$a_0 = 370{,}000$$
$$r = 1{\cdot}028 = 2{\cdot}8 \text{ per cent.}$$

Values computed from this result, viz.:

$$a_1 = (370{,}000)\ (1{\cdot}028)^{(t-1900)}$$

are given in column 4 of the following table, and the corresponding residuals in column 5. A glance at the figures in this last column will reveal the periodic nature of the increase in the population of the Cape Province during the past two hundred and fifty years.

The evidence is incontrovertible. The increase is not simply that of continuous geometric aggregation, but rather of geometric progression with a cyclical variation.

We have accordingly to solve the nineteen equations under the form:

$$(4) \quad . \quad . \quad . \quad . \quad a_1 = a_0 r^n k^{\cos(n\theta - M)};$$

when this was done there emerged the values:

$$a_0 = 386{,}385$$
$$r = 1{\cdot}0284 = 2{\cdot}84 \text{ per cent.}$$
$$k = 1{\cdot}2746$$
$$\theta = 2°{\cdot}1313$$
$$M = 318°{\cdot}55$$
$$n = (t-1900)$$

Therefore the white population of the Cape Colony, including the Transkei, at any time, t, will be

$$a_1 = (386{,}385)(1{\cdot}0284)^n (1{\cdot}2746)^{\cos\{n(2°{\cdot}1313) - 318°{\cdot}55\}}.$$

This equation indicates very interesting results. For example the periodic variation in rate is completed in :

$$\frac{360^\circ}{2^\circ{\cdot}1313} \text{ years} = 169 \text{ years.}$$

The changes in the rate of increase vary from 3·7 per cent. to 1·9 per cent. We are approaching this minimum at present in the Cape Colony. During the last decade the rate of increase has been very steadily declining. The lowest point ought to be reached according to the above elements in about five years.

The highest value, 3·7 per cent., was reached seventy years ago when the rate of increase was twice what it is to-day.

It is impossible to say what conditions govern these variations, but even against weighty authority we would venture to affirm that migration to and from these shores is not the chief controlling factor.

The following table sets forth the agreement between a purely geometric rate of increase computed from equation (1), and a periodic change in this geometric rate computed from equation (4).

The residuals in columns 6 and 8 are the tests of the correspondence between theory and observation.

Rotation No.	Year.	*n*.	Recorded population.	Computed population. Equation (1).	(O-C).	Computed population. Equation (4).	(O—C).
1	1672	−228	600	680	− 80	672	− 72
2	1690	210	1,330	1,120	+ 210	1,250	+ 80
3	1705	195	2,110	1,690	+ 420	2,090	+ 20
4	1744	156	5,150	4,970	+ 180	5,360	− 210
5	1765	135	8,630	8,870	− 240	8,030	+ 600
6	1770	130	9,000	10,190	− 1,190	8,880	+ 120
7	1775	125	11,000	11,700	− 700	12,400	− 1,400
8	1791	109	16,000	18,200	− 2,200	14,400	+ 1,600
9	1806	94	26,000	27,500	− 1,500	22,200	+ 3,800
10	1820	80	42,200	40,600	+ 1,600	34,000	+ 8,200
11	1849	51	93,000	90,400	+ 2,600	102,000	− 9,000
12	1856	44	119,000	110,000	+ 9,000	131,000	−12,000
13	1865	35	192,000	141,000	+ 51,000	178,000	+14,000
14	1875	25	241,000	185,000	+ 56,000	243,000	− 2,000
15	1891	−9	380,000	288,000	+ 92,000	377,000	+ 3,000
16	1901	+1	517,000	380,000	+137,000	474,000	+43,000
17	1904	4	580,000	413,000	+167,000	507,000	+73,000
18	1911	11	582,000	501,000	+ 81,000	581,000	+ 1,000
19	1918	18	619,000	643,000	− 24,000	667,000	−48,000
20	1921	+ 21	650,000	661,000	− 11,000	707,000	−57,000

There can be no doubt of the power of equation (4) to interpret the peculiar and variable increase of the white population in the Cape Colony during the past 250 years. Unless some unknown factor lies hidden in the figures, then equation (4) may be accepted, until some better exposition is forthcoming, as interpreting the variation in rate of the white population of the Cape Colony.

It is of deep interest, but foreign to the purpose of this paper, to associate historical or economic conditions with the ever-varying growth of population.

A yearly census of population, accurately taken, and wisely considered, would form a sensitive barometer for the winds of circumstance that blow over the land.

The director of the 1921 census, for example, frequently refers to the great influenza epidemic of 1918 as a potent influence in modifying the rate of increase of both white and black in South Africa. He could have gone further afield and shown how years of depression have brought down the totals below the estimated figures. A glance at the preceding table will abundantly prove this.

But as we have said, this is alien to our purpose, and much as one is tempted to do so, we may not follow the matter further. We hope, however, that the relation and response of population to economic and social circumstance will be considered by some other writer.

The diligent student will find in the introduction by Mr. Cousins to the 1921 census, pp. 17–24, a wealth of suggestion in this direction, and anyone anxious to pursue the investigation ought not to fail to make himself intimately acquainted with Mr. Cousins' judgments.

(3) Statistics of the White Population in Natal.

There is abundant material for a determination of the factors which govern the numerical growth of the European population in Natal, but unfortunately this material is not of very high quality.

We have already referred to the remark made by the director of the 1865 Cape census: "No census, in the proper acceptance of the term, has been taken of this colony before the present occasion." This could be uttered with far more truth of the Natal records. The annual blue-books are singularly full, but also singularly inaccurate. To give a very pertinent instance: The native population is given for each year to the last unit, but a footnote, with commendable honesty, states that the population is found by taking the huts upon which taxes are paid and then multiplying

this by a reasonable factor, the value of the factor being left to the compiler's imagination or knowledge.

It is when we are anxious to secure data which will stand the test of severe examination that one feels the inadequacy of such figures, except as a rough indication of the truth.

I have consulted such material as would correct or justify the Government figures, and as I have taken these from a number of sources, newspapers, gazettes, histories, records, travellers' tales, it is unnecessary to state the various authorities.

As in the case of the Cape Colony records, I have endeavoured to arrive at as near an approximation to truth as zeal and industry could afford. And in this direction I cannot speak too highly of the assistance given to me by the officials in the Parliamentary library.

Brooks, in his history of Natal, says that in 1835 the white population numbered sixteen.

But in these early, eventful years—years marked by blood and battle for the first pioneers into the Garden Colony—the population was a very fluctuating concern. So that it is unhelpful to include early figures into the present investigation.

The first year when anything approaching certainty is known with regard to the population of Natal is 1840. From that year onwards there are more or less reliable records.

Comparisons with regard to population can only be instituted when we are dealing with the same geographical area. Directors of census returns know the additional labour that changes in boundary cause, especially if synchronous estimates of population are not made.

In 1887 Zululand was taken over by the British Government, and ten years later it was annexed to the Colony of Natal.

In 1903 Vryheid and Utrecht were given to Natal.

In determining the population of Natal, allowance is made for these changes, and as far as possible the population taken or recorded prior to 1897 and 1903 is corrected to agree with the present geographical boundaries of the province.

The following table indicates determinations that are more or less reliable. The later the records the more exact naturally do they become, so that if a solution of extreme accuracy were sought the equations of condition would have to be weighted.

This is not done in the present investigation. I have only used such significant figures as may be relied upon. It may look very imposing in a table of populations where millions are involved to give the value to the last figure, but this is meticulous accuracy where the uncertainty runs to thousands.

White Population of Natal.

Rotation No.	n.	Year.	Recorded population.	Computed population. Equation (1).	(O−C.)
1	−60	1840	6,000	6,050	− 50
2	50	1850	9,000	8,910	+ 90
3	41	1859	11,600	12,600	− 1,000
4	39	1861	12,500	13,600	− 1,100
5	37	1863	14,000	14,700	− 700
6	36	1864	16,400	15,300	+ 1,100
7	29	1871	16,000	20,100	− 4,100
8	28	1872	18,400	20,900	− 2,500
9	26	1874	17,200	22,600	− 5,400
10	19	1881	27,000	29,600	− 2,600
11	15	1885	36,700	34,500	+ 2,200
12	13	1887	38,000	37,300	+ 700
13	9	1891	48,000	43,500	+ 4,500
14	− 8	1892	47,000	45,300	+ 1,700
15	+ 1	1901	95,000	64,100	+30,900
16	4	1904	97,000	72,000	+25,000
17	11	1911	98,100	94,400	+ 3,700
18	18	1918	122,000	123,700	− 1,700
19	+21	1921	136,800	138,900	− 2,100

A consideration of the enumerations recorded in the foregoing table, fourth column, first dealing with the increase as a simple geometrical acceleration according to the law,

$$a_1 = a_0 r^n,$$

gives as average values of a_0 and r

$$a_0 = 61{,}660$$
$$r = 1{\cdot}0395$$
$$= 3{\cdot}95 \text{ per cent.}$$

That is the average white population of Natal at any date, a_1, on a simple geometrical basis, and not taking into consideration any periodic variation in rate, is :

$$a_1 = (61{,}660)(1{\cdot}0395)^{(t-1900)}.$$

This average rate of increase, 3·95 per cent., means that the white population has been doubling itself every nineteen years. This very extraordinary increase has frequently been commented upon.

The director of the Union Census Returns for 1911, says (p. xiii) :—

> "The European permanent population of the states comprising the Union has, irrespective of additions through annexations, practically doubled itself in twenty years."

We have already seen that the average increase per cent. of the white population in the Cape Colony is 2·84, indicating a doubling every twenty-seven years.

But there are other equally interesting facts concerning the population of Natal which the student of Natal history will endeavour to relate to contemporaneous occurrences.

Thus, for example, there is a distinct decline in the increase from 1860 to 1870. Many people from Natal found their way, in that decade, to the diamond fields.

Again from 1898 to 1900 the increase was phenomenal, due, without doubt, to the influx of troops during the Anglo-Boer war.

But the most striking feature of the table is the clear evidence it supplies of a very distinct periodic variation. A superficial examination of the residuals in the last column will reveal this. Leaving out the population recorded in 1864, number 6 on the list, there is first a run of minus signs, then a run of plus signs, finally moving off again into minus values.

If these residuals be plotted down on a chart their circular character will be evident.

The form of the equation which we have chosen to represent periodic variation of this nature is

$$(4) \qquad a_1 = a_0 r^n k^{\cos(n\theta - M)}.$$

Changing this into its logarithmic form and solving the nineteen equations of condition represented in the table, we have these values :

$$\begin{aligned} a_0 &= 66{,}296 \\ r &= 1{\cdot}0427 \\ &= 4{\cdot}27 \text{ per cent.} \\ k &= 1{\cdot}1993 \\ \theta &= 7°{\cdot}108 \\ M &= 351°{\cdot}37 \end{aligned}$$

and as before $n = (t - 1900)$

so that the computed white population of Natal for any date a_1 would be :

$$a_1 = (66{,}296)(1{\cdot}0427)^n (1{\cdot}1993)^{\cos\{n(7°{\cdot}108) - 351°{\cdot}37\}}$$

or expressed in simpler logarithmic form :

$$\log a_1 = (4{\cdot}82149) + n(0{\cdot}018175) + 0{\cdot}078395 \cos\{n(7°{\cdot}108) - 351°{\cdot}37\}.$$

It is of interest to ascertain the quality of correspondence between the values computed from this latter equation and the recorded populations. The following table gives this correspondence :—

Rotation No.	*n*.	Year.	Recorded population.	Computed population. Equation (4).	(O – C.)
1	–60	1840	6,000	5,930	+ 70
2	50	1850	9,000	9,750	– 750
3	41	1859	11,600	12,200	– 600
4	39	1861	12,500	12,900	– 400
5	37	1863	14,000	13,400	– 600
6	36	1864	16,400	13,700	+ 2,700
7	29	1871	16,000	16,500	– 500
8	28	1872	18,400	17,200	+ 1,200
9	26	1874	17,200	18,700	– 1,500
10	19	1881	27,000	26,900	+ 100
11	15	1885	36,700	34,500	+ 2,200
12	13	1887	38,000	39,200	– 1,200
13	9	1891	48,000	50,400	– 2,400
14	– 8	1892	47,000	53,500	– 6,500
15	+ 1	1901	95,000	82,300	+12,700
16	4	1904	97,000	90,600	+ 6,400
17	11	1911	98,100	107,300	– 9,200
18	18	1918	122,000	123,500	– 1,500
19	+21	1921	136,800	135,100	+ 1,700

The residuals in the last column indicate how very closely the theoretical values interpret the very definite secular variation in population.

Except in two instances, 1864 and 1901, the difference between theory and observation is well within the margin of departure due to temporary fluctuations in the population. From this agreement one is compelled to accept a long-period cyclical variation in the rate of increase of the Natal white population as a real phenomenon.

Some very interesting facts emerge from a consideration of the secular formula.

The duration of the cycle is defined by

$$\frac{360^\circ}{\theta} = 50{\cdot}5 \text{ years.}$$

The rate per cent. of increase varies from 6·7 to 1·9 : the former extremely high rate was reached in 1885, and the minimum rate in 1913.

The years between 1883 and 1889 were years of phenomenal high

increase. The years between 1910 and 1915 marked the period of ebb tide in population. The rate of increase is now very slowly on the upward grade.

It will be observed that the period of low increase corresponds roughly with the same period for the Cape Province, that of Natal taking place a little earlier.

(4) Statistics of the White Population in the Orange Free State.

In 1836 what are now the fertile fields of the Orange Free State were described by a traveller who wandered over them as :—

> "A trackless desert, a howling wilderness, a land in which, though thinly populated by skulking broods of Bushmen, and by the starving remnants of nomadic pastoral tribes, which had been broken up by war and violence, no man permanently dwelt, neither was the soil any man's property ; a land in which for hundreds of miles the eye was not greeted by the smallest trace of human industry, or by any vestige of human habitation, the wild and interminable expanse ever presenting the same appearance, that of one vast uninhabited solitude."

About this time, however, European pioneers began to settle on the soil, "which was no man's property," and steadily the aspect of things changed. Cities sprang up in the wilderness, homes were raised, the "wild and interminable expanse" became the granary of South Africa, and what was in 1836 "a trackless desert, thinly populated by skulking broods of Bushmen and by the starving remnants of nomadic pastoral tribes," became in less than fifty years a well-governed and orderly state.

I have in my wanderings up and down the Union endeavoured to ascertain from old residents what it was that drew their fathers over the Orange River into these far-stretching plains. Apart from the natural trend of every southern soul to move northwards, there must have been a much more material beginning to the first migrations over the Orange River.

I am told that many of the farmers in the northern and eastern parts of the Cape Colony, round Colesberg, Graaff-Reinet, Somerset East and in the Albany district, knew of the vast herds of game that roamed almost unmolested over the great grass lands north of the Orange River, for the desolating wars of Tshaka, and the terrible famine that followed on these wars, had practically swept the now Orange Free State of native people.

So excursions and hunting expeditions were frequent occurrences : indeed it was these expeditions that gave to the old voortrekers the idea which eventually led them out into what was really a wilderness "where no

man dwelt." We shall refer to this again when dealing with the growth of the native population in the Orange Free State.

The earliest enumeration of the white population, of any value, was made in 1855, when it was estimated at 12,859 white people. No native census was taken, but their numbers would not likely be any less than this.

From this time down to 1880 it would appear that the Government relied on returns from magistrates, field-cornets, and ministers for information in this direction, but no attempt was made to systematise these various returns or to insist on their being faithfully and regularly seen to.

A rough estimate was made in 1877 which we have incorporated into our data, but the figures for this year are used only as a guide. They cannot be relied upon if not otherwise supported.

In 1880 we have the first official determination of the population of the Orange Free State. Several writers somewhat discredit the results obtained, but we do not think they merit the charge of being unworthy of acceptance.

The enumeration of 1890 was undertaken with very great care and completeness. One of the merits of this census is the thoroughness with which it enters into the numbering of the native population.

The various enumerations of 1904, 1911, 1918, 1921 need no explanation. They form part of the common system for the whole Union, and are characterised by great fulness and accuracy.

Grouping together all the available records of population we have the following table. The first record, that of 1845, is found in an early Geography of South Africa.

White Population of the Orange Free State.

Rotation No.	*n*.	Year.	Recorded population.	Computed population. Equation (1).	(O−C.)
1	−55	1845	2,000	23,500	−21,500
2	45	1855	12,900	31,000	−18,100
3	35	1865	15,000	40,900	−25,900
4	23	1877	45,000	56,900	−11,900
5	20	1880	61,000	61,800	− 800
6	−10	1890	77,700	81,500	− 3,800
7	+ 4	1904	135,400	120,000	+15,400
8	11	1911	175,200	145,600	+29,600
9	18	1918	181,700	176,000	+ 5,700
10	+21	1921	188,600	192,000	− 3,400

The first reduction of the values given in the fourth column of the above

table was by a consideration of the equations of condition according to the expression :

(1) . . . . . $a_1 = a_0 r^n$.

A solution of the ten equations gave the value :

$$\log r = 0{\cdot}012 : r = 1{\cdot}028 = 2{\cdot}8 \text{ per cent.}$$
$$\log E_0 = 5{\cdot}0312 : E_0 = 107{,}450,$$

yielding the expression

$$a_1 = (107{,}450)(1{\cdot}028)^n.$$

Values computed from this expression are given in the fifth column, and the difference between observation and theory in the sixth.

Now an examination of the residuals in this last column will amply prove the existence of a secular variation in rate. We have first a series of, on the average, decreasing negative residual values, then three positive values, then a return to the negative relation.

When these residuals are plotted down it is quite impossible to arrive at a periodic variation in rate, the time being too short in which to determine it ; but we have a very distinct secular change.

Dealing with the values in the fourth column under the definition :

(2) . . . . . $a_1 = a_0 r^n k n^2$,

or put logarithmically :

(3) . . . $\log a_1 = \log a_0 + n \log r + n^2 \log k$,

we find the following more satisfactory values as an interpretation of the white population of the Free State from 1845 to 1921 :

$$\log a_0 = \ 5{\cdot}0932 : a_0 = 123{,}940$$
$$\log r = +0{\cdot}0138 : r = 1{\cdot}0323 = 3{\cdot}23 \text{ per cent.}$$
$$\log k = -0{\cdot}00023 : k = (1{\cdot}00052)^{-1}$$

$$\therefore \qquad a_1 = (123{,}940)(1{\cdot}0323)^n (1{\cdot}00052)^{-n^2}$$

where $n = (t - 1900)$.

Values computed from this expression are given in the subjoined table, and anyone caring to compare the residuals for the first interpretation with those for the second will at once recognise the suitableness of the latter. We venture to think that the correspondence between theory and such an uncertain and unfathomable value as the rate of increase of population must always be, is more than we expected when we set out on this investigation.

The correspondence has led us to this belief that the variations in rate of increase of population is more subject to definite, if unknown, laws than the usual statistician is willing to admit.

Rotation No.	n.	Year.	Recorded population.	Computed population. Equation (2).	(O−C.)
1	−55	1845	2,000	4,330	− 2,330
2	45	1855	12,900	10,100	+ 2,800
3	35	1865	15,000	21,300	− 6,300
4	23	1877	45,000	45,000	
5	20	1880	61,000	53,000	+ 8,000
6	−10	1890	77,700	85,500	− 7,800
7	+ 4	1904	135,400	139,600	− 4,200
8	11	1911	175,200	165,100	+10,100
9	18	1918	181,700	185,200	− 3,500
10	+21	1921	188,600	191,500	− 2,900

Yet our whole actuarial principles are founded on the theory that variations in population can be subjected to exact laws.

The decline in the rate of increase of population in the Orange Free State is set forth in the following table :—

Year = 1850	. . . . .	increase per cent.	8·7
,, = 1860	. . . . .	,, ,,	7·6
,, = 1870	. . . . .	,, ,,	6·4
,, = 1880	. . . . .	,, ,,	5·3
,, = 1890	. . . . .	,, ,,	4·2
,, = 1900	. . . . .	,, ,,	3·2
,, = 1910	. . . . .	,, ,,	2·1
,, = 1920	. . . . .	,, ,,	1·1

It is evident on this theory of increase that the population of the Orange Free State will be soon stationary. The expression for such a point is found by differentiating the equation :

(2) . . . . . $a_1 = a_0 r^n k n^2$

that is

$$2n = \frac{\log r}{\log k}.$$

Putting in numerical values for log r and log k we have

$$2n = \frac{0{\cdot}0138}{0{\cdot}00023} = 60,$$

$$n = +30.$$

That is according to the above theory the stationary point in the white population of the Orange Free State should be reached about 1930.

It must be emphasised, however, that the change in rate may be periodic,

as in the case of the population of the Cape Colony and of Natal. But it is impossible to determine the duration of the cycle, the years during which exact data are available being too few. My own conviction is that the variation is periodic, and that the population of the Orange Free State is at present passing through a minimum phase. In another decade the population rate will begin to increase. All that the foregoing numerical argument tends to prove is that the rate of increase of the European population of the Orange Free State, whether secular or periodic, is passing its lower limit.

It is fitting here to give in full the words of Mr. Cousins on the law of population as found in the Census for 1921, p. 17 :—

> " Theories as to the law of population have been variously enunciated, but have been confounded by facts; and it is impossible to accept finally any theory yet advanced which would or could be applied unequivocally to divisions of mankind . . . . that there are laws it is impossible to dispute. There are occasions when investigators have glimmerings of their character, only to find themselves faced by conflicting or contributing factors, the force and effect of which has proved quite incalculable."

What we have dealt with here and in other parts of this paper is, of course, the reported figures of the past, and the theories which explain them. If deductions from these figures lead to certain conclusions with regard to the future these must not be accepted as rigorous statements of law.

Prophecy can have little place in population figures, for new elements of change may spring up, economical, physical, moral, spiritual, which will completely alter our equations, bringing into their operations new factors of immense potency.

(5) Statistics of the White Population in the Transvaal.

It is certain that many years before there was any attempt at ordered settlement in what is now known as the Transvaal Province, hunters from the north and east of the Cape Colony crossed its then fever-laden lands in search of game. There are still such legends abroad.

The first attempt at settlement was made in 1836 by Louis Trichard, who migrated from the Cape Colony with a party of 98 persons, of whom 64 were children.

Of this company of 98, after many weary wanderings and sad vicissitudes, 4 men, 3 women, and 19 children arrived at Delagoa Bay—the end of the first trek.

In 1838 Hendrik Potgieter recrossed the Drakensberg from Natal with a party of emigrant farmers, and established himself where the town of Potchefstroom now is.

When this first settlement took place the land was depopulated as far as natives were concerned. The devastating wars of Tshaka and Moselekatse had swept it almost bare of its old inhabitants. What were left of them had taken refuge in the rocks and caves of the Zoutpansberg, where, in their dire distress, many of them became cannibals.

For both the Transvaal and the Orange Free State the population between 1825 and 1835 may be regarded as negligible.

After 1840 settlement went steadily on : and the population must have increased very rapidly.

The discovery of the Gold Fields ushered in a new epoch for the Transvaal, naturally leading to a great increase in the population. It is possible that the recent discovery of platinum may bring about a similar leap forward in numbers in the near future. Exact figures regarding the population of the early days of the Transvaal are very difficult to obtain.

The 1904 Transvaal Census Report has this statement :—

> " Until 1890 no census was ever taken, and no reliable information of any kind can be found which will give any idea of the population."

It is true that no complete census was taken, but in 1876 an attempt was made in this direction. The result was, however, most unsatisfactory because of its incompleteness. No returns were made from some of the largest villages, field-cornetcies, and wards.

The 1890 census is almost equally unreliable. It would appear that no pains were taken to make it either accurate or complete.

From church records, magistrates' reports, old almanacs, and newspapers we are able to arrive at a rough estimate of some of the years prior to the taking of a census on a scientific basis.

Adding this imperfect data to the more perfect returns found in the various census reports, we have the following table of white populations :—

White Population of the Transvaal.

Rotation No.	n.	Year.	Recorded population.	Computed population. Equation (1).	(O—C.)
1	—45	1855	15,000	24,000	— 9,000
2	20	1880	40,000	75,900	— 35,900
3	—10	1890	113,713	120,200	— 6,500
4	+ 4	1904	297,277	229,100	+ 68,200
5	11	1911	420,562	316,200	+104,400
6	18	1918	499,347	436,500	+ 62,800
7	+21	1921	543,485	501,200	+ 42,300

As a first interpretation of the changes in population in the Transvaal the geometric formula

$$a_1 = a_0 r^n$$

was used, and the values which seemed best fitted to act as intermediary to a more rigorous solution were

$$a_0 = 190{,}550$$
$$r = 1{\cdot}047 = 4{\cdot}7 \text{ per cent.}$$

Values computed from this formula are given in the fifth column, and the corresponding residuals in the sixth column of the preceding table.

Now it does not require an examination of these residuals to prove that the population of the Transvaal has not increased according to the law of simple geometric progression.

Common knowledge, the incidents of political and economic history, tell us that this cannot be the case.

It is certain that there have been sudden changes in the growth of the population. It could not be otherwise. But mathematical treatment of such phenomena can take no cognisance of any *per saltum* alteration in the rate of progression. And this I do think is in accordance with the operations of natural law. As in investigations on the tides, there may be earthquake waves, storm waves, tidal waves, but the harmonic consideration of the rise or fall of the sea-levels leave these out of account in the study of the permanent forces which control the ebb and flow of the ocean. The incidental becomes merged in the permanent.

Now records of population are not sufficiently extended to allow of a cyclical interpretation of the variations in population of the Transvaal as we would desire to make, being convinced that it is the rational and real explanation of population variation, so we fall back on the simple secular interpretation.

Considering equation (2)

$$a_1 = a_0 r^n k^{n^2},$$

a solution yields the following values :

$$a_0 = 239{,}880$$
$$r = 1{\cdot}0593 = 5{\cdot}93 \text{ per cent.}$$
$$k = (1{\cdot}000933)^{-1}.$$

Therefore the expression for the reduction of the population to any date is

$$a_1 = (239{,}880)(1{\cdot}0593)^n(1{\cdot}000933)^{-n^2}.$$

Values computed from this expression are given in the subjoined table :—

Rotation No.	n.	Year.	Recorded population.	Computed population. Equation (2).	(O−C.)
1	−45	1855	15,000	2,700	+12,300
2	20	1880	40,000	52,000	−12,000
3	−10	1890	113,700	122,600	− 8,900
4	+ 4	1904	297,300	297,800	− 500
5	11	1911	420,600	404,700	+15,900
6	18	1918	499,300	501,900	− 2,600
7	+21	1921	543,500	535,200	+ 8,300

An examination of the residuals in the last column will indicate that the expression just given interprets the changes in population during the years when exact enumeration was made with an accuracy well within the probable errors of observation.

We may, therefore, consider that during the past thirty years the extended formula just given, including a factor expressing the steadily decreasing rate of increase, is an interpretation of the recorded enumerations.

The rate of increase in population since 1850, and certainly since 1890, is indicated in the following table :—

Year 1850	.	.	Annual rate of increase	=	16·3	per cent.
,, 1860	.	.	,, ,, ,,	=	14·2	,,
,, 1870	.	.	,, ,, ,,	=	12·1	,,
,, 1880	.	.	,, ,, ,,	=	10·0	,,
,, 1890	.	.	,, ,, ,,	=	7·9	,,
,, 1900	.	.	,, ,, ,,	=	5·9	,,
,, 1910	.	.	,, ,, ,,	=	4·0	,,
,, 1920	.	.	,, ,, ,,	=	2·1	,,

Between 1880 and 1890 the Transvaal white population trebled itself in ten years. The present rate of increase would mean a doubling of the white population in thirty-five years.

If the rate of increase is a continuously decreasing one then it follows that there must be a point in time when there is no increase. Such a point is reached when :

$$2n = \frac{\log r}{\log k} = \frac{0{\cdot}0251}{0{\cdot}000405} = 62$$

$$\therefore \quad n = 31.$$

That is the white population of the Transvaal according to the records of the past forty years should cease increasing in

1931,

when the white population should be

587,400.

But here again we incline to the view that the change in rate is periodic and not secular, that future determinations of population will prove that it is formula (4) and not formula (3) that must be used to interpret the changes in population. There is, however, not enough data at present to permit a reliable solution on this hypothesis. All that the various enumeratures indicate is that the white population of the Transvaal has been steadily declining in rate of increase during the past thirty years.

(6) An Investigation with regard to the Total White Population of the Union of South Africa.

This part of the investigation takes two directions: first, a rigorous determination of the present population and rate of increase as determined by recent enumerations; and, second, a less rigorous determination of the law of population of the Union during the past century as determined from estimated population arrived at by interpolation.

There are four important and exhaustive Union enumerations: those of 1904, 1911, 1918, 1921.

The 1904 enumeration took place before union, but it was undertaken with the full agreement of all the provinces, simultaneously, and under the same conditions.

The four totals are:—

1904 . . .	1,116,806
1911 . . .	1,276,242
1918 . . .	1,421,781
1921 . . .	1,519,488

The space in time over which these enumerations extend prohibit our attempting to determine any cyclical variation. There is a possibility of a secular variation appearing, and with this purpose in view the equation used in seeking to determine the law of increase was:

$$a_1 = a_0 r^n k^{n^2}.$$

Reducing these to logarithms we obtain four equations of condition which, when solved in the ordinary way, gave as values:—

$$a_0 = (1{,}039{,}340)$$
$$r = (1{\cdot}0186) = 1{\cdot}86 \text{ per cent.}$$
$$k = (1{\cdot}0000328)^{-1},$$

and the expression becomes:

$$a_1 = (1{,}039{,}340)(1{\cdot}0187)^n(1{\cdot}0000328)^{-n^2}.$$

Computing values from this and comparing we have the following correspondence :—

Year.	Observed population.	Computed population.	(O—C.)
1904	1,116,806	1,118,638	— 1,832
1911	1,276,242	1,269,083	+ 7,159
1918	1,421,781	1,435,136	—13,355
1921	1,519,488	1,511,304	+ 8,184

The correspondence between theory and enumeration is very marked. In no instance does the want of accordance reach 1 per cent.

The elements in the expression for the population during the years 1904–1921 indicate a fairly constant rate of increase of

1·87 per cent. per annum.

There is a small negative value depending on the square of the time which indicates that this increase is slowly decreasing. This present rate of increase, 1·87 for the European population of the Union, is too low for a young and virile land ; and whether we regard it as a value on a progressively declining scale, or a point near the minimum phase of a periodic fluctuation, as the curve represented on Chart, p. 227, would seem to indicate, it is not a heartening consideration.

This fact of decreasing rate is indubitable, and is one which should rouse more attention than it is doing. The question at issue is not so much the disparity between the white and the black population in South Africa, as the fact that the rate of increase of the white population, all over, shows a steady diminution.

At one time the increase per cent. per annum of the white population was over 5·0, now it has fallen below 2·0, a condition calling for investigation when we consider that this is a young country, of wide spaces, and with open doors to immigration,

With all the advantages South Africa offers, with its magnificent climate, its settled population, its future prospects, the annual increase per cent. ought not to be under 2·0, but somewhere in the region of 3·0.

It is of interest to indicate what the estimated white population of the Union has been since 1800.

The values are obtained by interpolation from those given in the several preceding tables. This may not be altogether satisfactory, but the numbers thus arrived at, since they are only declared in thousands, cannot be very far wrong. It is in extrapolation prophecy that one is apt to go very far astray.

The first numbers given for Natal, the Orange Free State, and the Transvaal are for 1840, but, as already indicated in the present papers,

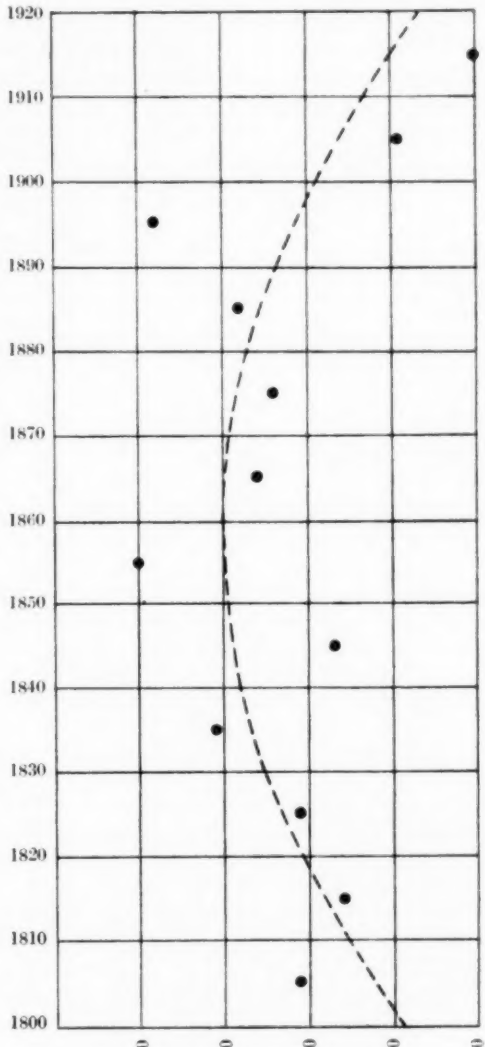

Chart showing the Variation in Rate of Increase for the White Population of the Union.

there were some white people in these provinces much prior to 1835. The few pioneers who did make their way into those inhospitable and unknown lands before this date were daring hunters and restless farmers from the Cape Colony, and may be counted as belonging to that colony.

The estimated white population is :—

Year.	Cape Province.	Natal.	Orange Free State.	Transvaal.	Total.
1800	22,000	..	..	..	22,000
1810	31,000	..	..	..	31,000
1820	42,000	..	..	..	42,000
1830	59,000	..	..	..	59,000
1840	77,000	6,000	1,000	5,000	89,000
1850	96,000	9,000	7,000	10,000	122,000
1860	151,000	12,000	14,000	18,000	195,000
1870	214,000	16,000	27,000	28,000	285,000
1880	284,000	26,000	61,000	40,000	411,000
1890	371,000	46,000	78,000	114,000	609,000
1900	505,000	93,000	118,000	244,000	960,000
1910	570,000	98,000	170,000	402,000	1,240,000
1920	637,000	134,000	186,000	528,000	1,485,000

Dealing with these figures in a far less rigorous but probably no less accurate manner than we have done hitherto, we have the following very interesting results, which, for convenience, we place in the form of a table :—

Increase per cent. in the White Population each Decade.

Decade.	Population at commencement of decade.	Increase during decade.	Per cent. per annum.
1800–1810	22,000	9,000	4·1
1810–1820	31,000	11,000	3·6
1820–1830	42,000	17,000	4·1
1830–1840	59,000	30,000	5·1
1840–1850	89,000	33,000	3·7
1850–1860	122,000	73,000	6·0
1860–1870	195,000	90,000	4·6
1870–1880	285,000	126,000	4·4
1880–1890	411,000	198,000	4·8
1890–1900	609,000	351,000	5·8
1900–1910	960,000	280,000	2·9
1910–1920	1,240,000	245,000	2·0
1920–	1,485,000	..	..

The residuals in the last column are expressed in a graphical form (Chart, p. 227), and I do not think there can be much doubt about the reality of the variable period.

The increase per cent. may be expressed in the following terms :

$$\text{Rate at any instant} = 3{\cdot}9 - 0{\cdot}0525t - 0{\cdot}000625t^2.$$

The average discordance when this equation is compared with the observed rate is only :

$$\pm 0{\cdot}7 \text{ per cent.}$$

It will be at once understood that this expression for the variable rate is only applicable to the period during which observations of population have been made. It would be unwise to apply it to future possibilities and probabilities.

We may indicate the change in rate in another form.

If the rate of increase that has governed the population during the past decade had operated during the century, then the population in 1800 would need to have been, not 22,000, but 170,000 ; or, put the other way, granting a start of 22,000, then the total white population in South Africa to-day would be only 200,000.

It is possible that the present decrease is only a passing phase, but it is disquieting to those who desire the welfare of South Africa.

(7) Statistics regarding the Native Population of the Union.

The question of native-population statistics is one of very great difficulty. This has been understood by those responsible for census reports : indeed the securing of accurate returns from native districts must give the director of any census or enumeration great concern.

We may mention two or three circumstances that affect the accuracy of native returns.

There is, in the first place, the fact that not infrequently the returning officer does not understand the language or the ways of the native people, and they understand the purpose and the manifestations of his mission still less.

Over and above this initial difficulty there are certain definite attitudes of the native mind to be taken into consideration. The native is naturally secretive when questioned. He is reluctant to reveal, for long centuries of savage life have taught him that questions mean trouble. Openness of mind comes with ages of freedom.

He is especially reluctant where numbers are concerned, for, with the present-day fiscal arrangements, numbers go hand in hand with taxation ; and in the past an inquiry by the chief regarding wives, children, cattle, kraals, meant much.

Over and above even these drawbacks to accurate enumeration, there is the want of care evidenced in many of the earlier returns, both as regards regions and race.

Take, for example, an instance out of the 1904 Cape Census. The Bantu returns are given as :

1865	100,236
1875	287,639
1891	838,136
1904	1,424,787

These numbers bear their own condemnation, for they would indicate an increase of 8 per cent. annually on the native population. The error lies in this that between 1865 and 1904 there was included within the geographical boundaries of the present Cape Province, Griqualand West, Bechuanaland, Kaffraria, and the Transkei, regions with a large native population, and the above figures disregard this fact.

Then again in Natal up to quite recently the native population was obtained by multiplying the number of huts on which a tax was made by a convenient factor.

These difficulties are mentioned in order to guard against a too explicit confidence in statistical reports dealing with natives, except where they are made with great care, much prudence, and unfailing fidelity to the pursuit of truth.

It may be of some interest to indicate the chief historical events in native history bearing on their population.

Towards the end of the sixteenth century the east-coast littoral was peopled by tribes of Bantu origin. From records left by Roman Catholic missionaries, and by Portuguese officials, these lands must have been very densely peopled. What is now the western and middle Transvaal, the Orange Free State, and practically the whole of the Cape Colony to near the Natal border, were held by natives of Bushman or Hottentot origin, and in the north and west Bechuanas and similar tribes were in possession of the land.

A natural instinct was drawing the Bantu tribes southward, and by the middle of the eighteenth century their van had reached the Kei River. There their advance was disputed by the Hottentots. One of the most bloody of native battles, one commemorated in native legend and song, took place at the upper of the fords of the Kei, for the Hottentot people understood dimly that at last they were fighting for existence.

The victory was to the Bantu people, who then streamed across the Kei into the fertile lands of Kaffraria, exterminating or absorbing the various Hottentot tribes they encountered.

Their progress was stopped at the Fish River, and although stray bands found their way as far west as Graaff-Reinet, the Fish River became for many a day the battle zone between the west and the east.

So long as they were on the march, and in almost constant warfare with the primitive peoples who had hitherto held the land, the Bantu tribes were at peace with one another; but with settled residence, and secure possession, ambitions and desire for supremacy stirred in the mind of many an able native. This is the path history usually takes with conquering peoples.

But during the latter half of the eighteenth century the Bantu occupation of the territories they had taken was one of quietness and of contentment. Travellers who then went through the land speak of the populous villages, the vast herds of cattle spread far and wide over the grass-lands, the evidences everywhere of settled conditions.

Shepstone, speaking of this time, considers that there must have been a million natives in Natal alone. Other writers and administrators speak in similar terms of the native occupancy of the northern provinces. Had this state of things continued, the history of South Africa would have been different.

But with the advent of the nineteenth century the spirit of adventure, of dominancy, of despotism, had full play. One great spirit after another conspired for mastery, till in Chaka the world saw one of its outstanding illustrations of ambitious endeavour.

Chaka was one of those strange souls that drift across life's stage for a space, and in that short space of time turn the world in which he moves upside down. His dominant and dominating spirit set the whole of Zululand aflame. Tribe impinged upon tribe. Men surged out from the centre of storm in great concentric circles, till away north of the Central African lakes, west to the shores of the Kalahari, south to the banks of the Umzimkulu, the pulsations of the military upheaval spent itself.

Years afterwards travellers crossing what had been populous districts saw nothing but the ashes of villages, desolate homes, impoverished fields, dead men's bones—the revealing tale of strife, and famine, and death.

South Africa, as far as its native population is concerned, was reborn after the Zulu upheaval.

Moderate estimates place the destruction of human life in the twenty years' strife between 1800 and 1820 at no less than two millions of people. So that, prior to 1820, or even 1830, we need not concern ourselves with the native population of South Africa.

Certain parts of the sub-continent remained for a long time in a state of disquietude. Such were Zululand and the Transkei. In the memory of

men still alive these now peaceful regions were battle zones. So that when we seek to deal with native population we must attach, as an explanatory label to our numerical statement, the history of the people enumerated. It is because of this that I have ventured upon the brief historical sketch just given.

The Cape Colony Proper.

As we have just said, the ama Ngqika tribes crossed over the Kei River and took possession of what is now the Ciskei, about the middle of the eighteenth century. They occupied the beautiful valleys of the Keiskama and the Tyumie and soon spread as far west as the Fish River.

For nearly a hundred years a constant struggle took place between them and the white pioneers moving eastwards and northwards. The last native war in the Ciskei took place in 1878, when the military power of the Ngqika tribes was for ever broken.

Kaffraria was declared in 1847 to be a British Province; previous to this date any determination of native population in the Ciskei territory is highly conjectural. Moreover, determinations of population could only be local, and at best uncertain, as each native war saw a redistribution of the population. In 1865 the province of Kaffraria was handed over to the Cape Colony for administrative purposes. The census taken this same year may be regarded as the first authoritative determination of native population in any part of South Africa.

In 1873 Griqualand West was declared a Crown Colony, and in 1890 was handed over to the Colony; Pondoland was annexed to the Cape Colony in 1894; British Bechuanaland in 1895.

In dealing with the European population great care was exercised to have the values for the same geographical area. Much more is this necessary in the case of native enumerations, where very frequently a very considerable portion of the population is in the portion not included then as an integral part of the Colony.

But here again, while the native population of the Colony then under administration from Cape Town may be very readily estimated, that outside, as for example the province of Kaffraria, of Griqualand West, of British Bechuanaland, must be highly conjectural.

I have endeavoured, however, with much labour, and with a result wholly incommensurate with the labour expended, to arrive at early estimates of the native population of the Cape Colony—excluding the Transkei—as it is at present defined geographically.

As the years pass, more and more will there be the desire to dispense with these conjectural values. I offer in excuse for their presentation that I do so with very great diffidence.

The following are the enumerations which may be accepted as reliable, especially the last four on the list :—

Native Population of the Cape Colony, excluding the Transkei.

Year	1849	population	197,000
,,	1856	,,	220,000
,,	1865	,,	313,000
,,	1875	,,	435,000
,,	1891	,,	535,000
,,	1904	,,	607,000
,,	1911	,,	640,000
,,	1921	,,	701,000

An analytical consideration of these values indicates a definite secular change, but the form of the curve is so steep that higher terms than the second have to be used to interpret it.

The first four values in the preceding table are so uncertain that I shall not burden this paper by giving the analytical solution. Rather I shall deal with the rate of increase in a much simpler way.

The following table will exemplify the method of approach ; the figures are taken from the preceding table :—

Rate per cent. of Increase at Succeeding Intervals.

Interval.	Years.	Population at beginning of interval.	Increase during interval.	Increase per cent.
1849–1856	7	197,000	23,000	1·67
1856–1865	9	220,000	93,000	4·70
1865–1875	10	313,000	122,000	3·90
1875–1891	16	435,000	100,000	1·44
1891–1904	13	535,000	72,000	1·04
1904–1911	7	607,000	33,000	0·78
1911–1921	10	640,000	61,000	0·95
1921–	..	701,000	..	..

These figures are illuminating. Leaving out the first interval, 1849–1856, where the low rate of increase is more than fully explained by the fact that the fierce war usually called the Third Kaffir Rebellion raged from 1850 to 1853, the other six rates, as recorded in the last column of the table, reveal one of the sad issues of the clash of two civilisations, this, that when a less richly endowed race comes into immediate contact with a more highly equipped people, it inevitably suffers numerically.

Benjamin Kidd, in his book Social Evolution, lays stress on this aspect of civilisation (pp. 46–58). To quote two sentences out of the many dealing with the subject, he says :

> " The weaker races disappear before the stronger, through the effects of mere contact."

And again :

> " We may beat our swords into ploughshares, but the implements of industry prove more effective and deadly weapons than the sword."

The report of the Hon. J. Ormsby-Gore to the British Government on the state of affairs in Central and East Africa also calls attention to the same conditions operating there.

To those of us who are deeply interested in our fellow-men this is a sad commentary upon our modern civilisation, and if we were not dealing with cold unresponsive figures we would be tempted to inquire more urgently if there were no way out of this shadow of death.

But since the figures are there, and are there indisputably, it will perhaps serve our purpose to state them, with the hope that they may increase interest in a question so vital to a large body of men in South Africa.

I shall place the European population and rate of increase since 1865, forty years ago, alongside the same figures for the native people of the Colony. The curious and the thoughtful may draw their own conclusions from it. I shall not in this instance pursue the matter further.

Comparative View of European and Native Rates of Increase.

No.	Interval.	Cape population. White.	Difference.	Rate.	Cape population. Native.	Difference.	Rate.
1	1856–1865	119,000	73,000	6·90	220,000	93,000	4·70
2	1865–1875	192,000	48,000	2·50	313,000	122,000	3·90
3	1875–1891	240,000	140,000	3·65	435,000	100,000	1·44
4	1891–1904	380,000	200,000	4·05	535,000	72,000	1·04
5	1904–1911	580,000	2,000	0·37	607,000	33,000	0·78
6	1911–1921	582,000	68,000	1·17	640,000	61,000	0·95
7	1921–	650,000	..	..	701,000	..	..

The Transkei.

The Transkei presents a remarkable native entity to the economist, the politician, and the statesman. It is a circumscribed area, unique as

regards history, political psychology, government, and ethnic ideals. Each of these directions of inquiry could well support an investigation of its own.

It is scarcely half a century ago since wars, tribal and otherwise, were the common experience of the people. I have met many a one, black and white, who has taken part in these early struggles.

But a succession of able administrators, a liberal policy of local government, wise native leaders, and the birth of liberal and progressive ideas have turned the once war-ridden land into a progressive and well-governed native province. Given a continuance of wise leaders and an understanding and sympathetic government, and the Transkei has a great future before it.

Records prior to 1875 are wholly unreliable. An enumeration guessed at in 1865 gives the population at 100,000; and an estimate by the Rev. H. Dugmore in 1847 gave the numbers of ama Gcaleka tribes as 70,000.

It is certain that at this latter date, however, a large portion of country lying between Natal and the Transkei was uninhabited. Its very name, No Man's Land, bears testimony to the condition of things the devastating wars of Chaka brought about in this part of South Africa.

Reliable enumerations are :—

Table of Transkei Native Population.

No.	Year.	Census population.	Computed population.	(O – C.)
1	1875	409,000	406,000	+ 3,000
2	1878	450,000	439,000	+11,000
3	1891	550,000	624,000	−74,000
4	1904	807,000	798,000	+ 9,000
5	1911	879,000	882,000	− 3,000
6	1921	939,000	936,000	+ 3,000

The values computed from the following expression :

$$a_1=(741{,}310)(1{\cdot}0199)^n(1{\cdot}00030)^{-n^2}(1{\cdot}000005)^{-n^3}$$

are found in the fourth column, and the residuals in the last. With the single exception of the third enumeration, that of 1891, the correspondence between theory and observation is very marked.

The third power in the equation for a_1 indicates how rapidly the Transkei increase is slowing down. This may be evidenced by an examination of

the enumeration for 1921 as compared with that of 1911. The increase is only 60,000 in a population of 879,000, indicating a yearly increase of only

0·68 per cent.,

while the average increase over the whole period is

2·0 per cent.

This increase is, of course, much lower than the corresponding European increase for the Cape Colony, but it only substantiates the truth we have been, perhaps unduly, pressing, that the native increase per cent. is far lower than the European for the same district.

Natal.

Enumerations with regard to the native population of Natal are many and inaccurate.

The Natal directories are a mine of more or less unreliable figures taken from the various Government Blue Books. We have already referred to the Natal official system of arriving at the native populations.

Newspapers, official documents, and other correspondence supply supplementary information.

One of the earliest estimates of the native population is one by West, when, in a document for the guidance of those interested, he says :—

> " These people (the natives) to the number of from 80,000 to 100,000, are scattered over a territory which seems to afford an abundant space of most fertile country for them, as well as for dense European population."

This report was written in 1846. Knowing the character of West, and his meticulous accuracy, we may accept a mean between his values as to the native population of Natal in 1846 ; that is,

90,000.

The other values I have obtained from directories, blue books (a failing well), newspapers, and other unofficial as well as official means of arriving at the truth, which, after all, ought to be the guiding principle in accepting such deadly things as figures.

In the list which I give of the native population of the Natal province, excluding Zululand, I have taken every thought-inspiring means of arriving at accurate figures, as I knew that the contact of a semi-civilised people with one—shall we so call it—more highly developed, was one which was bound to rouse controversy among very thoughtful men.

The enumerations which may be regarded as worthy of acceptance are the following :—

Native Population of Natal Proper.

No.	n.	Year.	Recorded population.	Computed population.	(O−C.)
1	−54	1846	90,000	79,000	+11,000
2	41	1859	140,000	145,000	− 5,000
3	37	1863	156,000	171,000	−15,000
4	36	1864	190,000	179,000	+11,000
5	33	1867	200,000	202,000	− 2,000
6	28	1882	346,000	351,000	− 5,000
7	15	1885	378,000	387,000	− 9,000
8	13	1887	409,000	412,000	− 3,000
9	− 8	1892	477,000	479,000	− 2,000
10	+ 4	1904	703,000	657,000	+46,000
11	11	1911	738,000	768,000	−30,000
12	+21	1921	889,000	903,000	−14,000

When these enumerations are dealt with analytically there is obtained the following values of the equation :—

$$a_1 = a_0 r^n k^{n^2}$$
$$a_0 = 595{,}670$$
$$r = 1{\cdot}0253 : \text{ increase per cent.} = 2{\cdot}5$$
$$k = (1{\cdot}00022)^{-1}$$

or combined :

$$a_1 = (595{,}670)(1{\cdot}0253)^n(1{\cdot}00022)^{-n^2}.$$

Values computed from this last expression are given in the last column but one of the table, and the accordance as exemplified in the last column is very marked.

Following the indications of this formula, we arrive at some very interesting extrapolation results.

The time when the decreasing rate will reach unity is arrived at when :

$$2n = \frac{0{\cdot}011075}{0{\cdot}000096} = 116 \text{ years.}$$

$$\therefore \quad n = 58 \text{ years.}$$

It follows that the stationary phase of the native population of Natal proper will be reached in

1958.

This is, of course, highly conjectural, as all extrapolation determinations must be, even when they are based upon the most reliable methods of analytical investigation.

At present the rate of increase of the native people in Natal proper is only

1·6 per cent. per annum.

The population, 1925, has already gone over the million mark, but aggregation goes on slowly, and if the preceding rigorous investigation be any indication of the condition of growth, it will still go on more slowly in the future.

Zululand.

We have dealt with Zululand separately from Natal because of the uncertainty with regard to its numbers.

As the Transkei was to the old Cape Colony, a kind of carbuncle on its eastern border, so was Zululand to the old province of Natal. It was the region from which sudden storms came.

It is very natural, therefore, that, except in an exceedingly rough way, in a way unsuited to critical scrutiny, it should have been very difficult to form an estimate of the population of Zululand in the days when it was not an integral portion of Natal.

During the first forty years of the nineteenth century Zululand was in the horrors of unrelieved war. Previous to that, say between 1750 and 1800, the native population of Zululand could not have been less than it is to-day, considering the armies that Tshaka and his immediate predecessors could put into the field.

It could not have been an impoverished country that supplied the men that to-day are found on the shores of Lake Nyasa, in Matabeleland, and in the Cape Colony. The exploring armies seem to have been drawn from an inexhaustible source.

One at times pictures the conditions in Natal and in Zululand had the Angoni not gone forth to Nyasaland, the Matabele to Rhodesia, the numerous tribes of the Fingos to the Cape Colony; if there had been no great upheaval a hundred and ten years ago; if the settled conditions that prevailed at the end of the eighteenth century had continued; if—— but we need not follow this train of thought. What we do know is that it was these early conditions of upheaval in Zululand that, by turning portions of the Transvaal and the Orange Free State into a no man's lands, gave the opportunity to the European pioneers to settle there.

We need not seek to arrive at even an approximate estimate of the

population of Zululand before its annexation in 1887; the earliest date at which we have reliable reports on the population is 1891, four years after annexation, and the year of the decennial census.

The population of Zululand at various dates is :—

No.	*n*.	Year.	Recorded population.	Computed population. Equation (2).	(O−C.)
1	− 9	1891	175,000	176,000	−1,000
2	+ 4	1904	201,000	200,000	+1,000
3	11	1911	215,000	217,000	−2,000
4	+21	1921	251,000	249,000	+2,000

The values from which the fifth column is computed are :

$$a_1=(191{,}000)(1{\cdot}0103)^n(1{\cdot}000115)^{n^2}.$$

Two conditions call for remark here : first the low rate for Zululand, 1·03 per cent., and second the fact that this rate is an increasing one. The Zululand rate is half that of Natal proper, but as just said the rate is an increasing one, against the Natal decreasing rate.

The accuracy with which the formula just given responds to the actual enumerations is exceedingly remarkable; the want of correspondence as seen in the last column is never greater than 1 per cent.

The Orange Free State.

No attempt was made by the Republican authorities to arrive at an estimate of the native population in the State. The need for such an enumeration did not appeal to those men who really ruled their country so wisely and so well. So long as there was sufficient labour for the farms then matters were well, and to secure this necessary labour natives were invited to come from adjoining territories, especially from Basutoland.

Early enumerations are practically valueless. There are three such before me :—

1855= 5,000
1865=10,000
1875=15,000.

Now the native population of Thaba'nchu alone, at all points of the chequered history of this people, was more than the above.

The values which we may accept as reliable are :—

No.	n.	Year.	Recorded population.	Computed population.	(O—C.)
1	—10	1890	120,000	120,000	..
2	+ 4	1904	229,000	239,000	—10,000
3	11	1911	326,000	316,000	+10,000
4	+21	1921	422,000	435,000	—13,000

When the values in the fourth column are dealt with in the ordinary way there is made evident the following numerical values of the equation :

$$a_1 = a_0 r^n k n^2$$
$$a_0 = 200,130$$
$$r = 1{\cdot}0476$$
$$= 4{\cdot}76 \text{ per cent.}$$
$$k = (1{\cdot}00046)^{-1}$$

which gives as a numerical statement for the value of the native population of the Orange Free State at any instant :

$$a_1 = (200,130)(1{\cdot}0476)^n (1{\cdot}00046)^{-n^2}.$$

Attention may be directed to the very high annual rate of increase :

4·76 per cent.

This, however, is militated against by the rapid reduction of this rate, which would reduce this increase in fifty years to zero.

There is not the least doubt that the Orange Free State has profited by drafts from Basutoland ; so that it is impossible to offer any definite views on the native population increase in the Orange Free State until the circumstances of the Basutoland rate has been inquired into.

The Transvaal.

The native population of the Transvaal presents a very difficult problem to the statistician.

There is the native living tribally in purely native areas ; there is the native servant, or squatter, on farms ; there is the mine worker and store boy living in town compounds or locations. The population is fairly equally divided between these three classes, the first class, the tribal native, being in the majority.

The last class is a constantly fluctuating one in numbers, and this will

always render it difficult to arrive at a theory of population for the Transvaal.

As in the case of the Orange Free State, no serious attempt was made by the old Government to number the native people. So all estimates previous to 1880 may be set aside.

The enumerations which I purpose using are :—

No.	n.	Year.	Recorded population.	Computed population.	(O—C.)
1	−10	1890	649,000	609,000	+40,000
2	+ 4	1904	937,000	977,000	−40,000
3	11	1911	1,220,000	1,198,000	+22,000
4	+21	1921	1,496,000	1,539,000	−43,000

The computed values found in the fifth column are obtained from the expression

$$a_1=(861{,}600)(1{\cdot}033)^n(1{\cdot}00023)^{-n^2}.$$

The annual rate of increase

3·3 per cent.

is a fairly large one, but against this there is the fact of a very distinct annual diminution represented by the factor

$$(1{\cdot}00023)^{-1}.$$

The correspondence between observation and theory is not very marked, due to the fluctuating condition of the labour market in Johannesburg.

These irregularities disappear when all the native territories are combined together.

Combined Native Population.

It is not possible to obtain massed population figures earlier than 1891 ; and census directors have wisely confined themselves to enumerations taken later than 1890.

There are four very well-defined totals available for analytical scrutiny, the census figures of 1891, 1904, 1911, and 1921. The figures are, of course, for the Union ; although for this geographical area they are complete.

Because that the figures are confined to the Union, they fail to give all the information that a rigorous inquiry seeks to obtain.

To secure this condition, when a comprehensive survey might be instituted, Basutoland and Swaziland would have to be included.

We have already pointed out that the native population of the Orange

Free State is very largely recruited by emigration from Basutoland, and the population of the Transvaal by the influx of people from Swaziland.

At present, however, we will confine ourselves to the mass numbers of natives in the Union.

The combined figures are :—

No.	n.	Year.	Recorded population.	Computed population.	(O—C.)
1	— 9	1891	2,504,000	2,510,000	—6,000
2	+ 4	1904	3,484,000	3,485,000	—1,000
3	11	1911	4,019,000	4,013,000	+6,000
4	+21	1921	4,699,000	4,699,000	..

The formula from which the values set forth in the fifth column is :

$$a_1=(3{,}179{,}800)(1{\cdot}0242)^n(1{\cdot}000256)^{-n^2}.$$

The closeness with which theory corresponds with observation is indicated by the residuals in the last column. The agreement is extraordinary ; the mean difference is less than one in a thousand, indicating the reality of the law of increase that we have formulated.

The remarkableness of the agreement induces one to venture forth, unwillingly, into extrapolation figures. It is a safe margin, however, to move out into the future no further than the space of time in which we have exact data and on which our formula is based.

The value r will cease to exist as a factor greater than unity at the instant when

$$2n=\frac{\log r}{\log k}=\frac{\cdot 010410}{\cdot 000111}$$

$$n=47.$$

This result indicates that in 1947 the native population in the Union will be practically stationary. They will then number

6,300,000.

It is understood that this argument is based on the assumption that the present conditions, or rather the conditions operating during the thirty years 1891 to 1921, remain unchanged. Altered economic conditions, different social and political circumstances, newer ideas and aspirations among the native peoples may modify the factors that govern the progression of population. But that modification can only operate within very strictly defined limits, limits determined by employment, land pressure, food, and similar circumstances of natural life.

(8) Conclusions.

In the course of this paper I have dealt with many general conclusions to which the present investigation seems to lead.

The less important of these I need not again restate. There are some, however, that because of their import call for singular attention, and may profitably be stated here :—

(1) The rate of increase of the population of South Africa is in no single instance, European or Native, a constant one. That is to say, the theoretical computation of the population does not depend upon the simple statement :

$$a_1 = a_0 r^n$$

where r is an invariable quantity.

(2) The rate of increase is subject to constant, and when taken over a long period regular, change ; so that the theoretical population is better expressed by the equation :

$$a_1 = a_0 r^n k^{n^2}$$

where both r and k are invariable factors.

(3) It is quite evident from a rigorous investigation into the laws which apparently govern the change in rate that a simple expression including the square of the time will not wholly explain the variation.

The further back we are able to push our inquiry into the rate of increase the more is it evident that any expression which seeks to interpret the changes in the amount of this rate must depend even on higher powers than the square of the time. We will require at least to include a term depending upon the cube of the time. Such an expression cast into logarithmic mould would be

$$\log a_1 = \log a_0 + n \log r + n^2 \log k_1 + n^3 \log k_{11} \ldots$$

We have not ventured to determine the higher terms in this series, but we are confident of their existence from the curious result that the mean rate for 1900 comes out very much higher when we use earlier enumerations as the bases of our investigations, than it does when we make it to depend upon recent figures.

(4) The vagations in rate of the population of the Cape Colony and of Natal indicate a cyclical variation ; one full period has been described in both instances.

Indeed it is possible that that population rate of all the provinces is subject to a periodic variation, only in the nature of things the time over which exact data is available is too short to permit a determination of the duration of the cycle for the two northern provinces. If we admit this possibility, then the rate of increase of the European population of the

Transvaal and of the Orange Free State is not diminishing without limit, but is passing through a minimum phase, as is the case with the population of the Cape and of Natal. It is but reasonable to expect that the population rate of all the provinces would vary synchronously. The expression per cyclical variation is :

$$\log a_1 = \log a_0 + n \log r + \log k \{\cos (n\theta - M)\}.$$

(5) Enumerations of European population during the past twenty years show a steadily declining rate in every province. The rate is now less than 2 per cent. for the whole Union.

There must be beneath this definite decreasing rate certain influences—political, economic, social, climatic—which produce it. It should be the grave concern of the State to find out what those influences are. A regularly increasing population is an important indication of the well-being of a state.

(6) Enumerations of native population during the same period indicate also a declining rate.

The rate for 1900 was 2·4 per cent., but the decrease on this value is eight times the European decrease per annum.

The population of Zululand is the only section of the Union that shows a slight increase in rate during the period in which exact data are available.

(7) Certain changing conditions in Native life are related to, or connected with, this rapid declining rate. There is the increasing movement city-ward, where infant mortality is high, over 50 per cent. in some urban locations. There is the steady decrease of polygamy (1921 Census, vol. viii., p. 102) ; in 1925 only one married native in nine is a polygamist. There is, also, the altered economic, domestic, and travelling conditions superimposed upon Native life and custom. There is the steady impoverishment of the land. All these have naturally tended to lessen the rate of increase of the Native people.

(8) A full inquiry into the relative increase of the races in South Africa should take into account the population of both Basutoland and Swaziland, as these areas are large feeders of the Transvaal and the Orange Free State.

THE HYDROLYTIC PROPERTIES OF CERTAIN AMINO-ACIDS.

By Louis Pierre Bosman.

Introduction.

The object of the investigations described below is to discover whether certain amino-acids have any definite hydrolytic action on esters of a particular type. Very little work in this direction has, up to the present, been done, but certain very definite conclusions have been arrived at. Falk and Nelson, who investigated this matter at great length, appear to be convinced of the fact that the esters cited below are hydrolysed—some to a smaller and some to a greater degree—by the amino-acids in question.* It is very doubtful, however, whether these investigators have taken into consideration all the factors before drawing their conclusions. There is no evidence that the hydrogen-ion concentrations of the reacting solutions have been taken into account. It is obviously a factor of no small importance, without a consideration of which very erroneous inference may be drawn, as is shown in this paper.

Experimental.

For the following experiments methyl acetate, ethyl butyrate, and olive oil were used—being representatives of a typical water soluble ester, water insoluble ester, and of a substance representing fats respectively. The olive oil was neutral, and the esters, as supplied by May & Baker, were specially purified. Glycine, alanine, leucine, and aspartic acid were samples of Merck's purest reagents. The glutamic acid was not obtainable locally, and was therefore prepared from gluten flour. It was repurified several times.

In each case 0·1 gram of the substance, 1 c.c. of the ester, and 25 c.c. distilled water were used. A 1 per cent. alcoholic solution of phenolphthalein as indicator, and N/10 NaOH were used to determine the extent of hydrolysis. The amount of acid was estimated by the formol method of Sørensen.† The addition of the neutral formalin, however, is unnecessary.

* J. Amer. Chem. Soc., xxxiv, 1, 755 (1912).

† Biochem. Z., 7, 45 (1907).

The results of the first series of experiments are tabulated in Table I. These, of course, are the averages of several experiments. Each individual result is the mean of at least four or five determinations. This was deemed advisable, as the degree of hydrolysis in many cases is so small.

TABLE I.

1	2	3	4	5	6	7
Substance.	Time.	Glycine + ester + water.	Glycine + water.	Ester + water.	Degree of hydrolysis.	Ester.
A GLYCINE	24	12·87	12·71	0·1	0·06	Me. Ac.
	24	13·08	12·66	0·1	0·32	Et. Bu.
	24	12·87	12·66	0·05	0·16	O. O.
		Alanine + ester + water.	Alanine + water.	Ester + water.	Degree of hydrolysis.	Ester.
B ALANINE	23	9·02	8·86	0·1	0·05	Me. Ac.
	24	9·20	8·84	0·1	0·26	Et. Bu.
	24	9·05	8·84	0·05	0·16	O. O.
		Leucine + ester + water.	Leucine + water.	Ester + water.	Degree of hydrolysis.	Ester.
C LEUCINE	25	5·67	5·62	0·1	0·06	Me. Ac.
	25	6·03	5·64	0·1	0·39	Et. Bu.
	25	5·84	5·63	0·05	0·16	O. O.
		Aspartic acid + ester + water.	Aspartic acid + water.	Ester + water.	Degree of hydrolysis.	Ester.
D ASPARTIC ACID	24	13·4	11·7	0·1	1·6	Me. Ac.
	24	12·2	11·7	0·1	0·4	Et. Bu.
	24	12·3	11·7	0·05	0·55	O. O.
		Glutámic acid + ester + water.	Glutamic acid + water.	Ester + water.	Degree of hydrolysis.	Ester.
E GLUTAMIC ACID	24	11·3	10·5	0·1	0·70	Me. Ac.
	24	11·0	10·5	0·1	0·40	Et. Bu.
	24	10·6	10·5	0·05	0·05	O. O.

The figures in columns 3 and 5 represent the number of c.c. N1/0 NaOH required for the neutralisation of the acids produced by the substances there specified. The amounts of the reacting substances have been given above. In column 4 we have the amount of alkali required to neutralise the aqueous solution of the acid itself. The actual degree of hydrolysis is thus got by difference and is expressed in column 6, and

represents the number of c.c. of N/10 NaOH required to neutralise the acid liberated from the esters on incubation. In the last column the particular ester used is cited. The time is in hours, and the temperature at which the experiments were conducted throughout ranges from 37–38° C.

In these estimations the formol method of Sørensen was utilised.

Except for the hydrolysis of methyl acetate by aspartic acid and glutamic acid, it would appear from the results tabulated that the several hydrolyses are but small. Ethyl butyrate is seemingly hydrolysed by glycine, alanine, and leucine to a greater extent than methyl acetate and olive oil. There can be no doubt, however, that these results generally do not warrant the drawing of absolutely definite conclusions. Several of the hydrolyses are hardly beyond the bounds of experimental error. It is, of course, true that Falk and Nelson obtained a slightly greater degree of hydrolysis in some cases, but taken as a whole the results in Table I. agree fairly well with those of these authors.

In cases where the degree of hydrolysis is so small, it is a matter of great importance to take into consideration the acidity of the amino-acids—*i.e.* the hydrogen-ion concentration of the medium in which the hydrolysis is in progress. It is not impossible that the hydrolysis may be due to the comparatively prolonged action of a slightly acid medium.

With this object in view the hydrogen-ion concentration of each acid was carefully determined, and the hydrolytic power of corresponding solutions compared with those of the amino-acid solutions.

A. Glycine.—In the case of glycine Sørensen's phosphate mixture was used. A M/15 solution of secondary sodium phosphate ($Na_2HPO_4 \cdot 2H_2O$) was carefully prepared in the usual manner. It was analysed as to its water content both before and after exposure. In conjunction with this a M/15 primary potassium phosphate was used. In both cases Merck's purest chemicals were employed.

Using brom-cresol-purple as indicator, it was found that 10 c.c. of a 0·4 per cent. solution of glycocoll in water possesses the same hydrogen-ion concentration as a mixture of 1 c.c. secondary and 9 c.c. primary phosphate. This gives the solution of glycine a $P_H = 5{\cdot}9$.

A mixture of the two phosphates in the above proportions was made and the hydrolytic power of it tested on the three esters. In each case 25 c.c. was treated with 1 c.c. of the ester.

The methyl acetate, ethyl butyrate, and olive oil were hydrolysed to the extent of 0·06, 0·33, 0·17 c.c. respectively. These figures are more or less identical with those obtained in Table I., A.

B. Alanine.—The hydrolytic power of alanine and that of a solution of M'Ilvaine's phosphate-citrate mixture was next compared. It was found

that a 0·4 per cent. solution of alanine has a hydrogen-ion concentration of 6·0, *i.e.* the same as that of 12·63 c.c. of 0·2 M secondary phosphate and 7·37 c.c. of 0·1 M citric acid. As above, the results agreed very closely with those in Table I., B.

C. Leucine.—The hydrogen-ion concentration of leucine was determined as above and found to be 5·2, and the results of the hydrolysis with the phosphate-citrate mixture were determined. Again the results approximated very closely to those of Table I., C.

The results discussed on p. 247 are more interesting than important, as it has already been noted that the hydrolyses are too small to be considered significant. The same applies, therefore, to the results in Table I., A, B, and C.

D. Aspartic Acid.—In the case of aspartic acid, however, we find that the methyl acetate is hydrolysed to a perceptible degree. We are again confronted with the same problem. Is this due to the amino-group, or is it due to the acidity of the medium ?

With brom-phenol-purple as indicator and M'Ilvaine's standards it was found that a 0·4 per cent. solution of aspartic acid has the same hydrogen-ion concentration as a mixture of the phosphate and citric acid in the proportion of 4·1 to 15·9 respectively—viz. $P_H = 3·0$.

Since the hydrolysis of methyl acetate is the only one that is marked, the hydrolytic powers of aspartic and glutamic acids on it alone were further investigated.

In the first instance 25 c.c. of the standard in the correct proportions were incubated with 1 c.c. methyl acetate for twenty-four hours. This experiment was repeated a large number of times, so as to reduce any possible errors. The several results were considered together and the average result taken.

This was again repeated and the two mean results are given in Table II.

TABLE II.

Time.	Phosphate citric acid + ester + water.	Phosphate citric acid alone.	Ester + water.	Degree of hydrolysis.
24	55·80	54·40	0·1	1·3
24	55·98	54·40	0·1	1·48

The results obtained here are more or less the same as those with methyl acetate in Table I., D.

Unfortunately in the above experiments the titre in each case is rather

large compared with the previous results. For this reason the same experiments were performed, leaving the mixtures to incubate for 48, 72, and 96 hours. This then would reduce the relative errors. The results of these experiments are tabulated in Tables III. and IV. for the phosphate mixture and the aspartic acid respectively.

TABLE III.

Methyl acetate.	Time.	Phosphate citric acid + ester + water.	Phosphate citric acid alone.	Ester + water.	Degree of hydrolysis.
	48	56·13	54·30	0·1	1·7
	72	56·50	54·40	0·2	1·9
	96	56·60	54·60	0·2	1·8

TABLE IV.

Methyl acetate.	Time.	Aspartic acid + ester + water.	Aspartic acid alone.	Ester + water.	Degree of hydrolysis.
	48	9·0	7·2	0·1	1·7
	72	9·1	7·2	0·2	1·6
	96	9·0	7·2	0·2	1·6

The outstanding features of the results in Tables II., III., and IV. are that

(1) There seems to be no appreciable difference in the degrees of hydrolyses of methyl acetate with aspartic acid on the one hand and with the phosphate citric acid mixture on the other.

(2) The aspartic acid (Table IV.) shows no increase in hydrolysis over a period of two, three, or four days. In the case of the phosphate citric acid mixtures there is a slight increase, but nothing very striking. This was somewhat unexpected, so the experiments were repeated several times; but the results obtained were no different from those in Tables III. and IV.

There seems to be very little room for doubting that *the hydrolysis brought about by the aspartic acid is entirely due to the acidity of the medium.*

Both from the evidence before us and the evidence to be cited, we cannot but conclude that the amino-group is not responsible for this hydrolysis; but the problem was investigated from this viewpoint as well.

0·5 gram of aspartic acid was dissolved in about 80 c.c. distilled water at a slightly elevated temperature (40° C.). The solution was then neutralised with N/10 NaOH, and made up to 125 c.c. with distilled water. This solution was employed for a set of similar experiments to those in Tables I., D, and II.

TABLE V.

Methyl acetate.	Time.	Neutralised aspartic acid + ester + water.	Neutralised aspartic acid alone.	Ester + water.	Degree of hydrolysis.
	24	0·20	0·0	0·1	0·1
	24	0·20	0·0	0·1	0·1
	24	0·20	0·0	0·1	0·1

We notice, therefore, that the degrees of hydrolyses of methyl acetate with neutralised aspartic acid are, for all practical purposes, negligible. This points to the fact that the property assigned to the amino-acid by Falk and Nelson is not tenable, *i.e.* that the hydrolysis is due to the amino-group. It is more probably due to the acidity of the medium. Further evidence for this assertion is given in the following experiments.

The experiments, the results of which are tabulated in Table V., were repeated in another way.

5·0 grams of aspartic acid were added in small quantities to 100 c.c. warm distilled water in which about 3·0 grams of the purest obtainable anhydrous sodium carbonate were dissolved. Eventually the solution was slightly acid, and sodium carbonate was added in small quantities until it was just neutral to litmus. The solution was taken down to half its volume, but no crystals separated out on standing. On further concentration the solution acquired a thick, syrup-like consistency. To this was added twice its volume of absolute alcohol and the mixture briskly agitated and scratched, when an immediate separation of crystals took place. The sodium aspartate crystallises in beautiful arborescent monoclinic needles. It was recrystallised from 60 per cent. alcohol. It melts sharp at 143° C., and the yield was 5·4 grams. Taking aspartic acid to behave as a mono-basic acid, the theoretical yield is 5·8 grams. It crystallises without any molecules of water of crystallisation. A 0·4 per cent. aqueous solution of the salt was prepared, in accordance with the other experiments, and its hydrolytic power tried. In each case 25 c.c. of the solution was taken along with 1 c.c. of the methyl acetate, and the usual blank experiments conducted simultaneously.

It is evident, therefore, that the sodium aspartate does not hydrolyse the ester.

TABLE VI.

Methyl acetate.	Time.	Aspartate + water + ester.	Aspartate alone.	Ester + water.	Degree of hydrolysis.
	24	0·2	0·1	0·1	Nil.
	24	0·2	0·1	0·1	Nil.
	24	0·2	0·1	0·1	Nil.

We have now studied the action of the aspartic acid, the neutralised aspartic acid, and the sodium salt. To complete this line of investigation we shall consider the hydrolytic power of succinic acid itself.

A 0·4 per cent. aqueous solution was prepared as before, and its hydrogen-ion concentration was determined by means of Sørensen's glycocoll-hydrochloric acid mixture and using thymol-blue as indicator. It was found to be the same as that of a mixture of 8 c.c. of glycocoll and 2 c.c. N/10 HCl—viz. P_H=2·8. The experiment was carried out with the same quantities as before and the results tabulated in Table VII. In Table VIII. we have the results of the mixture of glycocoll and hydrochloric acid itself.

TABLE VII.

Methyl acetate.	Time.	Succinic acid + water + ester.	Succinic acid alone.	Water.	Degree of hydrolysis.
	24	18·1	16·0	0·1	2·0
	24	18·1	16·0	0·1	2·0
	24	18·2	16·0	0·1	2·1

TABLE VIII.

Methyl acetate.	Time.	Glycocoll mixture + ester + water.	Glycocoll mixture alone.	Ester + water.	Degree of hydrolysis.
	24	7·7	5·5	0·1	2·1
	24	7·8	5·5	0·1	2·2
	24	7·6	5·5	0·1	2·0

Seemingly, therefore, the hydrolysis is due to the acidity of the succinic acid. This is, of course, what we expect. Then again, the fact that the

degree of hydrolysis brought about by the succinic acid is greater than that occasioned by the aspartic acid, is doubtless due to the greater ionisation constant of the former.

E. Glutamic Acid.—The glutamic acid required for these experiments was prepared from gluten flour. The method adopted was that given in Cole's handbook on Practical Physiological Chemistry, 6th ed., p. 78.

Its hydrolytic power was ascertained, and this was compared with a mixture of M'Ilvaine's phosphate citric acid standards. The P_H was found to be equivalent to the phosphate citric acid in the proportion of 5·3 to 14·7 respectively—viz. 3·3. As before, methyl acetate was the ester used, with the following results :—

TABLE IX.

Methyl acetate.	Time.	Glutamic acid + ester + water.	Glutamic acid alone.	Ester + water.	Degree of hydrolysis.
	24	7·38	6·6	0·1	0·68
	24	7·40	6·6	0·1	0·70
	24	7·40	6·6	0·1	0·70

TABLE X.

Methyl acetate.	Time.	Phosphate citric acid + ester + water.	Phosphate citric acid alone.	Ester + water.	Degree of hydrolysis.
	24	51·61	50·80	0·1	0·71
	24	51·50	50·60	0·1	0·80
	24	51·55	50·70	0·1	0·75

These figures lead us to the same conclusion, *i.e.* that hydrolysing property is concerned with the acidity of the medium rather than with the amino-group in the acid. Further, the figures given in Table IX. agree fairly well with those in Table I., E.

The author thought that there was just a slight possibility that the acid itself might undergo hydrolysis to some small extent when exposed to a temperature of 38° C. for the comparatively long period of twenty-four hours, in which case a further correction would have to be made. 25 c.c. of each of the freshly prepared acids were then titrated before and after incubation, with the following results :—

TABLE XI.

Time.	Substance.	c.c. N/10 NaOH required to neutralise solution. *Before* incubation.	c.c. N/10 NaOH required to neutralise solution. *After* incubation.
24	0·1 gram of glycine in 25 c.c. H_2O.	0·6	0·6
24	0·1 gram alanine in 25 c.c. H_2O.	0·5	0·5
24	0·1 gram leucine in 25 c.c. H_2O.	0·4	0·4
24	0·1 gram aspartic acid in 25 c.c. H_2O.	7·3	7·3
24	0·1 gram glutamic acid	6·6	6·6

The acid itself, therefore, appears to undergo no change on exposure to this temperature for twenty-four hours.

The hydrogen-ion concentrations of the above acids in a 0·4 per cent. solution was also determined electrometrically, and the results agree fairly well with those found colorimetrically.

In conclusion, the author wishes to extend his thanks to Professor E. S. Edie of this University for the interest taken in, and the valuable suggestions given for, this investigation.

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THE PREPARATION OF UMBELLIFERONE.

By Ernest George, B.A., M.Sc., A.I.C.

(Communicated by Dr J. Moir.)

Umbelliferone, being required in quantity in connection with the work described in the next paper, was prepared by the method of v. Pechmann (Berichte, xvii, 932). In this process, equimolecular quantities of resorcinol and malic acid are heated together with concentrated sulphuric acid.

When the supply of commercial *l*-malic acid had given out, and synthetic *r*-malic acid had perforce to take its place, some interesting anomalies were obtained.

In my hands v. Pechmann's process did not give the yields claimed by him. Several variations of his procedure were tried, and finally the following modified process was adopted :—

26·8 grams malic acid and 22 grams resorcinol were ground up together and gently heated with 54 c.c. concentrated sulphuric acid. The liquid solidified in a few minutes to a light yellow mass, and then quickly remelted while effervescing strongly. Heating is stopped as soon as liquefaction is complete, and the mass is immediately poured into 220 c.c. ice-water. v. Pechmann heated the mixture strongly, and stopped heating only when effervescence had ceased.

The umbelliferone takes three days to separate completely, and then appears as a light red crystalline mass. After two recrystallisations from dilute alcohol and one from dilute acetic acid it was pure, of a faint yellow colour, and melted at 225° C. The yield was 12 grams. Approximately, this yield persisted in further experiments, whereas v. Pechmann claimed 16·2 grams.

For the preparation from synthetic *r*-malic acid, the latter was obtained by the hydrolysis of *r*-$\gamma\gamma\gamma$-trichloro-β-hydroxybutyric acid, which was prepared according to the conditions laid down by Thurnlackh (Monatsh., 1891, xii, 556).

The hydrolysis was carried out with very dilute potassium hydroxide, and the neutralised solution was treated with barium chloride, which precipitated barium *r*-malate. The latter was removed by filtration, washed, and decomposed in aqueous suspension with the calculated quantity

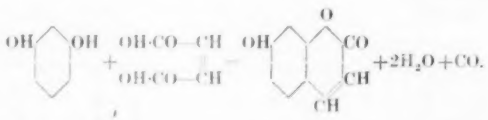
of oxalic acid. When the barium oxalate had been removed, the filtrate was taken to dryness in a vacuum over concentrated sulphuric acid, and the *r*-malic acid purified by solution in acetone and precipitation by xylene.

In several preparations of umbelliferone from *r*-malic acid, using the same weights of materials as before, an average yield of 15·5 grams resulted. In a similar experiment, using commercial *l*-malic acid which had been purified by solution in acetone and precipitation by xylene, and which had the correct melting-point of 100° C., a yield of 12·5 grams umbelliferone resulted.

As *r*-malic acid persistently gave larger yields of umbelliferone than *l*-malic acid, it was decided to attempt a synthesis from *d*-malic acid, as by analogy a still larger yield could be expected. This proved to be the case.

d-malic acid was prepared from *l*-$\gamma\gamma\gamma$-trichloro-β-hydroxybutyric acid as directed by M'Kenzie and Plenderleith (Journ. Chem. Soc., London, 1923, cxxii, 1090). Two preparations were carried out from this *d*-malic acid, and the weights of materials and conditions of experiment were the same as before. The yields were 16·8 and 17·2 grams of umbelliferone respectively.

There does not appear to be any strong reason why any one form of malic acid should react more readily than any other form. The only difference is in the spacing of the α-hydroxyl group. It was decided to eliminate this group and to attempt to prepare umbelliferone from maleic acid and from fumaric acid. The reactions could be expected to proceed as follows, and would probably give increased yields in the case of maleic acid :—



Neither of these acids appears to have been condensed with resorcinol, but maleic anhydride, when heated with resorcinol without a condensing agent, gave malein-fluorescein, a substance which dissolves in alkalies with a wine-red colour, showing a green fluorescence (Burckhardi, Berichte, xviii, 2864).

Fumaric acid and resorcinol were condensed together as follows :—

Twenty-five grams fumaric acid and 22 grams resorcinol were ground together and heated with 50 c.c. concentrated sulphuric acid with constant stirring. The liquid solidified to a light-yellow mass after nine minutes' heating, and then remelted with effervescence. When cool, the melt was added to 200 c.c. ice-water. After three days the precipitate was washed

free from acid. The method of purification was as before, and resulted in umbelliferone in a yield of 22·1 grams. The melting-point was 223° C., either alone or when mixed with umbelliferone from malic acid.

Found C=66·2 ; H=3·7 per cent.
$C_7H_6O_3$ requires C=66·6 ; H=3·8 per cent.

Maleic acid and resorcinol were condensed together by exactly the same method. In this case, however, the solidifying of the melt occurred within six minutes of commencing to heat. The liquid after remelting was dark in colour, and a small quantity when dissolved in sodium hydroxide solution gave a red colour with a green fluorescence. It was apparent that some malein-fluorescein had formed. The purification of the umbelliferone in this case is similar to that produced from fumaric acid, but is more protracted. The yield is hence much lower. In three experiments, yields of 10·4, 12, and 13·6 grams were obtained, an average of 12 grams.

The yields of umbelliferone, as obtained from the various acids, are as follows :—

Acid used.	Percentage yields of pure umbelliferone obtained.
Commercial *l*-malic acid	37
Pure *l*-malic acid	38·6
r-malic acid	48
d-malic acid	52
Fumaric acid	70
Maleic acid	37

SOME PHTHALEIN ANALOGUES.

By Ernest George, B.A., M.Sc., A.I.C.

The substances described in this paper are phenol-umbellein, resorcinol-umbellein, phenol-cinnamein, phenol-phthalamein, resorcinol-phthalamein, and so-called "phenol-5-methylisatin."

With the exception of the last-named, all are of the phthalein type. Phenol-5-methylisatin is isomeric with the possible but as yet unprepared phenol-5-methylisatein.

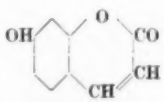
On these grounds it was considered advisable to present them all in one paper.

A. The Umbelleins.

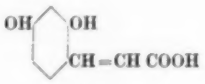
These compounds were prepared as part of an investigation which aimed at an explanation of that qualitative test for malic acid whereby the latter, when heated with resorcinol and concentrated sulphuric acid, gives a melt which dissolves in alkali solutions generally to produce a nearly colourless solution with a blue fluorescence, but occasionally a red solution with a green fluorescence.

The action of sulphuric acid on equimolecular proportions of resorcinol and malic acid to produce umbelliferone has been fully worked out by the author, and is discussed in the preceding paper. Umbelliferone dissolves in alkalies to give a pale yellow solution possessing a strong blue fluorescence. Its dilute ammoniacal solution gives a narrow absorption band at λ 354. The fluorescence is absent in neutral solution and commences to be visible at *p*H 7·2.

Umbelliferone has now been further condensed with phenol and with resorcinol. The products formed are, following the nomenclature of phenol-phthalein, phenol-umbellein and resorcinol-umbellein. Umbelliferone reacts as the lactone of umbellic acid (2 : 4-dihydroxycinnamic acid).

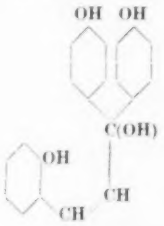


Umbelliferone.

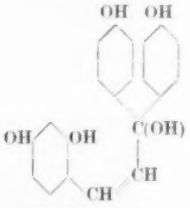


Umbellic acid.

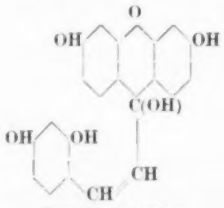
Krishna (J. Chem. Soc., London, 1921, clxiv, 1420) condensed phenol with coumarin, the lactone of 2-hydroxycinnamic acid, and obtained phenol-coumarein, having the structure



It is hence to be expected that phenol-umbellein and resorcinol-umbellein have analogous structures, namely,



Phenol-umbellein.



Resorcinol-umbellein.

Phenol-umbellein was prepared as follows: 6 grms. umbelliferone, 8 grms. phenol, and 4 grms. dry powdered zinc chloride were heated together until melted, and a current of dry hydrochloric acid gas was passed through while the temperature was kept constant at 120° C. The mixture soon became pink, and then darkened until, after six hours, it was quite black. The melt was poured, while still hot, into 200 c.c. 5 per cent. hydrochloric acid, and steam was passed through until all unused phenol had been removed. After cooling, the dark red precipitate was filtered off and again boiled with dilute acid. After twenty-four hours the red precipitate was filtered off, washed, dissolved in 200 c.c. 3 per cent. sodium hydroxide solution, and permitted to stand overnight. Next morning the solution was filtered, whereby some small tarry lumps were removed, and again precipitated with dilute hydrochloric acid. Solution was then effected in sodium carbonate solution, and, after filtering, the precipitate was re-formed with dilute acid. This was repeated twice more, and the final washed precipitate was recrystallised from hot dilute hydrochloric acid.

As thus obtained, phenol-umbellein is a red crystalline powder. After drying for a long time at 80° C. in a vacuum over concentrated sulphuric acid, its melting-point was 88–90° C., with decomposition. The yield was

2·1 grms. In other experiments, using as condensing agents strong sulphuric acid, zinc chloride alone, anhydrous aluminium chloride, and stannic chloride, the yields were always very small.

Phenol-umbellein is very slightly soluble in water and easily soluble in hot dilute hydrochloric acid. It is soluble in alcohol and in glacial acetic acid. Alkaline solutions have a ruby-red colour, which is changed to a light yellow by excess of acid. The colour change is between *p*H 3·7 and 5·2. A solution in ammonia, when greatly diluted, gives a narrow absorption band at λ 543.

Analysis gave C=72·6 ; H=5·3 per cent. $C_{21}H_{18}O_5$ requires C=72 ; H=5·14 per cent.

Attempts at acetylation gave only tarry products, and it was apparent that much decomposition had occurred.

Resorcinol was condensed with umbelliferone as follows : 7·5 grms. umbelliferone, 11 grms. resorcinol, and 5 grms. dry powdered zinc chloride were heated in a current of dry hydrochloric acid gas at 120° C. for five hours. The mixture darkened rapidly and ultimately became black. It was poured, while still hot, into 200 c.c. boiling 4 per cent. hydrochloric acid and boiled for some time. On cooling, the dark-coloured precipitate was filtered off, dissolved in sodium carbonate solution, and precipitated by dilute acid. This was repeated three times. It was then dissolved in alcohol, water was added until a turbidity appeared, and the solution was heated with animal charcoal. The compound, thus purified, still tenaciously retained some impurity, and it was redissolved in sodium carbonate solution and fractionally precipitated with dilute hydrochloric acid. After drying for a long time in the steam-oven it darkened at 175° C. and decomposed about 180° C.

Found C=68·8 ; H=4·5 per cent. $C_{21}H_{16}O_6$ requires C=69·2 ; H=4·4 per cent.

An attempt was made to prepare resorcinol-umbellein directly from malic acid and resorcinol, using concentrated sulphuric acid as a condensing agent. Using various temperatures and periods of heating, and purifying the product as above, the best yield was nearly 3 per cent. of the theoretical.

Resorcinol-umbellein is a dark red powder, insoluble in water, but soluble in alcohol and in glacial acetic acid. It dissolves in alkalies, forming dark red solutions which show a strong green fluorescence. A dilute ammoniacal solution gives a narrow absorption band at λ 482.

Tetrabromoresorcinol-umbellein was prepared as follows : 3 grms. resorcinol-umbellein were dissolved in 20 c.c. glacial acetic acid, and a solution of 1 c.c. bromine in 10 c.c. glacial acetic acid was added. The mixture was permitted to stand overnight. A small amount of tarry material separated, and the solution was filtered and poured into 300 c.c.

water. The bulky red precipitate which formed was filtered off and washed. After prolonged drying in the steam-oven it darkened on heating and decomposed about 180° C.

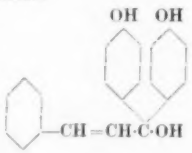
Found Br=47·6 per cent. $C_{21}H_{12}O_6Br_4$ requires Br=47·1 per cent.

Tetrabromoresorcinol-umbellein is a dark red powder, insoluble in water, but soluble in alcohol, glacial acetic acid, and alkalies. It shows no fluorescence at all in any solvent. The ammoniacal solution is dark violet-red with strong tinctorial properties, and, when very dilute, shows a narrow absorption band at λ 505.

The qualitative test for malic acid is thus explained. According to the proportions of malic acid and resorcinol used, and the extent of heating, either umbelliferone or resorcinol-umbellein is formed. The former causes the blue fluorescence with alkalies, and the latter the red solution and green fluorescence.

B. Phenol-cinnamein.

This compound is the parent substance of phenol-coumarein and phenol-umbellein. It has the structure



and is thus the styryl-derivative of Moir's *p* – *p'*-dihydroxybenzhydrol (Trans. R. Soc. S. Afr., 1921, p. 66).

It was prepared as follows: 10 grms. cinnamic acid, 13·5 grms. phenol, and 5 grms. anhydrous powdered zinc chloride were heated together at 120° C. for six hours. The mixture soon became yellow, and then red, and finally almost black. It was poured, while still hot, into 300 c.c. 3 per cent. hydrochloric acid, and boiled for some time to remove phenol and zinc chloride. On cooling, a semi-solid, tarry material separated. This was filtered off, dissolved in very dilute sodium hydroxide solution, and precipitated by means of dilute acid. A yellow precipitate settled and a tarry material floated. The latter was removed, and the yellow precipitate was again dissolved in sodium hydroxide solution. The result was a clear, wine-red solution, which, when nearly neutralised by means of dilute acid, gave a purple precipitate. The latter was filtered off, washed with water, dilute hydrochloric acid, and distilled water in turn. There thus resulted 3 grms. of a yellow powder, which dissolved in alcohol, and was obtained crystalline by slow evaporation of the latter. When kept for several days, or when heated in the steam-oven, the colour changed to a dark red.

Found C=78·7 ; H=5·8. $C_{21}H_{18}O_3$ requires C=79·2 ; H=5·7.

Phenol-cinnamein, when heated, commences to decompose at 115° C. It is insoluble in water, but soluble in alcohol and in glacial acetic acid to form brownish-yellow solutions. It is soluble in alkali solutions, giving a purple-red solution which turns yellow when acidified. The colour change is from *p*H 2·4 to 4·6. A very dilute alkaline solution gives a narrow absorption band at λ 565.

Attempts were also made to prepare resorcinol-cinnamein from cinnamic acid and resorcinol, but with no success. The product of the condensation, using zinc chloride, is a dark red substance, which is apparently a complex mixture. When dissolved in sodium hydroxide solution and fractionally precipitated, a dark red fraction was obtained in small quantity. This gave with alkalies a light red solution, with a strong green fluorescence and a narrow absorption band at λ 493. On heating it decomposed.

This condensation has also been carried out by Bargellini and Marantonio (Atti R. Accad. Lincei, 1908, xvii, 119), who obtained from the melt 2 : 4-dihydroxyphenyl styryl ketone, and by Short and Smith (J. Chem. Soc., London, 1922, ccxvii, 1808), who obtained resaurin and styrene.

C. "Phenol-5-methylisatin."

Baeyer and Lazarus (Berichte, xviii, 2637) observed that coloured solutions were formed when a solution of potassium ferricyanide was added to their "phenolisatin."

During the progress of an investigation which aims at determining the constitution of these coloured substances, phenolic condensation-products of many substituted isatins have been prepared.

It is proposed to describe here phenol-5-methylisatin as an example.

Many substituted isatins had first to be obtained, and these were prepared by a modification of the process of Geigy (Chem. Zentra., 1920, iv, 223).

The details in the case of 5-methylisatin were as follows: 10 grms. *p*-toluidine were dissolved in just sufficient hydrochloric acid, and the solution diluted to 150 c.c. with water. 7 grms. hydroxylamine hydrochloride were added, and the mixture boiled; while a solution of 30 grms. bromal hydrate in 130 c.c. water was run in during five minutes. After boiling for another five minutes the solution was rapidly cooled. Oximinoaceto-*p*-toluidide (which can also be termed Isonitrosoacetyl-*p*-toluidine) separated out, and was filtered off, washed, and dried. The yield was 8·2 grms.

The reactions that occur are represented in the following equations :—

$$CBr_3CHO + NH_2OH = CBr_3CH : NOH + H_2O$$
$$CBr_3CH : NOH + CH_3C_6H_4NH_2 + H_2O = CH_3C_6H_4NH \cdot CO \cdot CH : NOH + 3HBr.$$

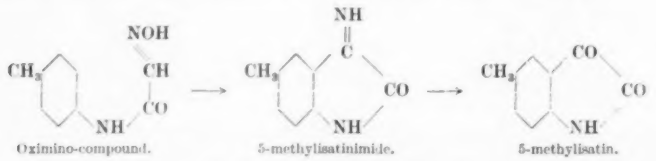
The yield is seriously influenced by boiling the mixture too long or by failure to cool sufficiently rapidly. Chloral hydrate can replace the bromal hydrate, but smaller yields result.

The dry oximinoaceto-*p*-toluidide was added in small portions at a time to 20 c.c. concentrated sulphuric acid. Heat was evolved, and the temperature was maintained, during the addition, at 60–65° C. When all had been added, the temperature was raised to 75° C. for another ten minutes. 5-methylisatin was precipitated by pouring the mixture into 100 c.c. ice-water. For purification it was dissolved in the minimum quantity of dilute sodium hydroxide solution and reprecipitated with dilute hydrochloric acid. The first portions of the precipitate were tarry, and were rejected. Solution and precipitation were repeated, and the 5-methylisatin finally filtered off, washed, and dried.

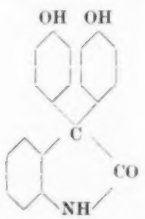
It was now pure, of a bright crimson colour, and melted at 187° C.

Found C = 66·8 ; H = 4·4 per cent. Calculated for $C_9H_7O_2N$; C = 67·1 ; H = 4·4 per cent.

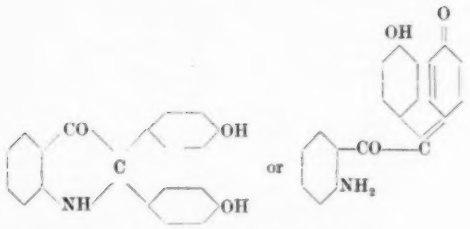
The action of concentrated sulphuric acid on the oximinoaceto-*p*-toluidide and subsequent dilution with water are represented as follows :—



Baeyer and Lazarus condensed phenol with isatin and obtained " phenol-isatin," to which, without stating any reasons, they assigned the structure

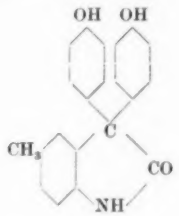


Had isatin reacted as the lactam of isatic acid or o-aminobenzoylformic acid, the product which formed would have been phenol isatein of the structure



This compound, phenol isatein, in which the phenol has entered the carboxylic carboxyl group, could naturally be expected to produce coloured solutions with alkalies. Baeyer's compound, however, gives no colour with alkalies.

For similar reasons, phenol-5-methylisatin, which is correctly named 5-methyl-3-3′-bis-4-hydroxyphenyl-oxindole, is represented as follows :—



For the preparation of this compound the following procedure was adopted : 16 grms. 5-methylisatin were dissolved in 32 grms. phenol by warming on the water-bath. Concentrated sulphuric acid was then added, drop by drop, until the crimson colour had faded to a light yellow. The mixture was then at once poured into water, when phenol-5-methylisatin was precipitated.

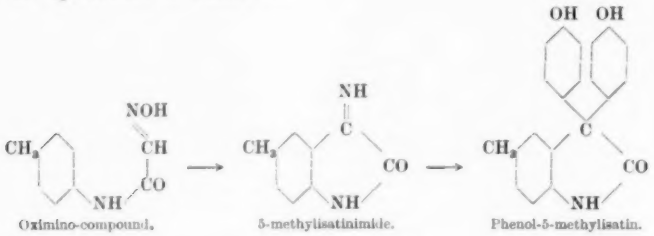
The fact that condensation occurs with such ease, and that no prolonged heating is required, is additional evidence that the condensation-product is not of the phthalein type.

The impure 5-methylisatin, as precipitated, was dissolved in ammonia and reprecipitated by dilute acid. It was then dissolved in ether containing a little alcohol and treated with chloroform. This caused a slow precipitation. After filtering, it was found that prolonged heating in the steam-oven was required before constancy of weight was reached. It was probable that an ether-addition-compound had been produced. The dry compound melted at 246–248° C.

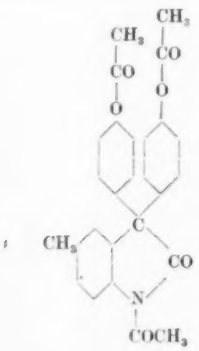
Found C = 75·6 ; H = 5·2 per cent. $C_{21}H_{17}O_3N$ requires C = 76·1 ; H = 5·1 per cent.

As thus obtained, phenol-5-methylisatin was quite colourless, insoluble in water and chloroform, soluble in alcohol and in ether containing a little alcohol. It dissolved in alkalies to form *colourless* solutions, from which it was precipitated unchanged by acids.

Phenol-5-methylisatin was also produced directly from oximinoaceto-*p*-toluidide. The latter was dissolved in concentrated sulphuric acid, and the temperature taken to the correct figure, as before. This produced 5-methylisatinimide in solution. When cool, the calculated quantity of phenol was stirred in, and the phenol-5-methylisatin precipitated by pouring into water. It was purified as before, and melted at 248° C. The reactions in this case can be represented as follows :—



Triacetylphenol-5-methylisatin



This compound was obtained by heating together phenol-5-methylisatin, acetic anhydride, and anhydrous sodium acetate. After recrystallisation from alcohol it melted at 191° C.

Found C=70·4 ; H=5·1 per cent. $C_{27}H_{23}O_6N$ requires C=70·9 ; H=5·03 per cent.

Further work on these condensation products will be published later, including an account of their oxidation to colouring matters.

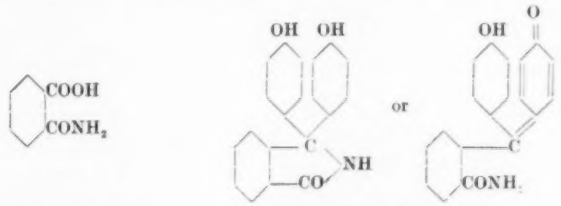
D. The Phthalameins.

These compounds were prepared for the purpose of measuring the effect on the colour produced by replacing the anhydride oxygen atom in the phthaleins by the imide-group.

It was also desired to compare phenol-phthalamein with the isomeric substance, "phenolisatin," mentioned above.

Phthalimide and phenol condense together very easily in the presence of concentrated sulphuric acid, and the pure product is obtained in a 60 per cent. yield, which is rather exceptional for this type of condensation.

The phthalimide reacts as the lactone of phthalamic acid, and hence the condensation product is phenol-phthaleinimide or phenol-phthalamein.



Phthalamic acid. Phenol-phthalamein.

In a typical experiment, 15 grms. phthalimide, 20 grms. phenol, and 8 c.c. concentrated sulphuric acid were heated at 110° C. for twenty-four hours. The excess phenol was distilled off in steam, and, after cooling, the light-coloured residue was filtered off. It was purified by dissolving in ammonia and precipitating with dilute hydrochloric acid. This was repeated twice, and a third time the alkaline solution was all but neutralised with dilute acetic acid and the precipitate filtered off. After drying in the steam-oven it melted at 260° C., with decomposition. The yield was 18·6 grms.

Phenol-phthalamein is a *light yellow* powder; it dissolves in alcohol, and the solution, on slow evaporation, deposits light yellow needles. It is insoluble in water and ether. Alkaline solutions have a *ruby-red* colour. A dilute ammoniacal solution gives a narrow absorption band at λ 555. The corresponding figure for phenol-phthalein is λ 554.

When alkaline solutions are treated with excess acid the colour disappears. The range is slightly shorter than in the case of phenol-phthalein, being *p*H 7·9 to 9. Phenol-phthalamein is hence an excellent substitute for phenol-phthalein as an acid-alkali indicator.

Analysis gave N = 4·6 per cent. $C_{20}H_{15}O_3N$ requires N = 4·4 per cent.

Acetic anhydride in the presence of pyridine gave a diacetyl derivative, which separated from dilute alcohol as a crystalline powder, melting at 256° C.

Found C=71·5; H=4·9 per cent. $C_{24}H_{19}O_5N$ requires C=71·8; H=4·7 per cent.

Benzoyl chloride, with a solution of the substance in sodium hydroxide, gave a dibenzoyl derivative which separated from hot water as a crystalline powder which decomposed when heated.

Found C=77·7; H=4·6 per cent. $C_{34}H_{23}O_5N$ requires C=77·7; H=4·4 per cent.

Resorcinol-phthalamein, prepared and purified by a method exactly similar to that used for phenol-phthalamein, was obtained as a yellow powder that could not be obtained crystalline.

Found C=71·8; H=4·3 per cent. $C_{20}H_{13}O_4N$ requires C=72·2; H=3·9 per cent.

When heated, resorcinol-phthalamein begins to decompose at 198° C. It is nearly insoluble in water, but dissolves in alcohol with a yellow colour. Alkaline solutions have a yellow colour, with a powerful green fluorescence. The dilute ammoniacal solution gives a narrow absorption band at λ 489. Acids convert the colour to a lighter yellow, and destroy the fluorescence.

The phthalimide used in these experiments was prepared by the method of Herzog (Zeitsch. Angew. Chem., 1919, xxiii, 301) by heating together phthalic anhydride and urea. The yield was found to be almost theoretical, and the phthalimide gave the correct melting-point after only one washing.

NOTE ON DECREASE IN ACIDITY DURING RIPENING OF GRAPES.

By P. R. v.d. R. Copeman, B.A., B.Sc.

(With two Text-figures.)

The most important factors which determine the quality of a fruit are the sugar and acid content, and in previous work upon the ripening of grapes * it has been shown that the most important changes are those taking place in these two factors. The total acidity, as determined by direct titration of the juice, exhibited a continuous decrease during the periods of investigation. The decrease, however, did not remain uniform, but gradually became less until, at full maturity, the amount of acid remained very nearly constant.

In a paper † on " The Changes in Acid Content of Stored Apples " it has been shown that the acidity of apples decreases during storage, and that the change in acidity follows a logarithmic curve. It was also found that the rate of loss of acidity in apples stored at ordinary temperatures differed from that in apples in cold storage, being greater at the higher temperature. It is clear, therefore, that the changes in acid content under these circumstances is influenced by external conditions such as temperature.

Since there is a decrease in acidity during the ripening of grapes, it was thought that possibly these changes could also be expressed by a logarithmic function. This has been found to be the case, at any rate, during the period of ripening. The observations include the determinations of acidity made in 1923 and 1925 during work upon the ripening of grapes. However, in both cases, the work was commenced at a stage when the initial onset of ripening had started, and there are therefore no data for a comparison to be made with the changes occurring while the amount of acid is increasing.

Tables I. and II. have been taken from the work already mentioned.

* Copeman, " An Investigation into some Physical and Chemical Changes occurring during the Ripening of Grapes," Department of Agriculture Bulletin, Division of Chemistry Series 31, 1924. Copeman and Frater, " Some Physical and Chemical Changes occurring during the Ripening of Grapes," 1925 (unpublished manuscript).

† Haynes, Ann. Bot., 49 (1925), 77.

TABLE I.

Grapes pressed in 1923.

Acidity as Grammes of Tartaric Acid per 1000 *c.c. Juice.*

Date.	Days.	White Hanepoot.	Red Hanepoot.	Barbarossa.	Flaming Tokai.
31.1.23	0	..	19·2	..	..
7.2.23	7	14·4	9·9	12·5	15·6
14.2.23	14	11·4	10·6	12·4	12·9
21.2.23	21	8·5	8·8	9·3	12·1
28.2.23	28	7·6	6·8	7·8	9·2
7.3.23	35	6·8	5·4	6·6	7·0
14.3.23	42	5·6	5·4	6·1	6·2
21.3.23	49	4·9	4·5	4·7	6·0
28.3.23	56	5·2	4·4	4·5	4·4

TABLE II.

Grapes pressed in 1925.

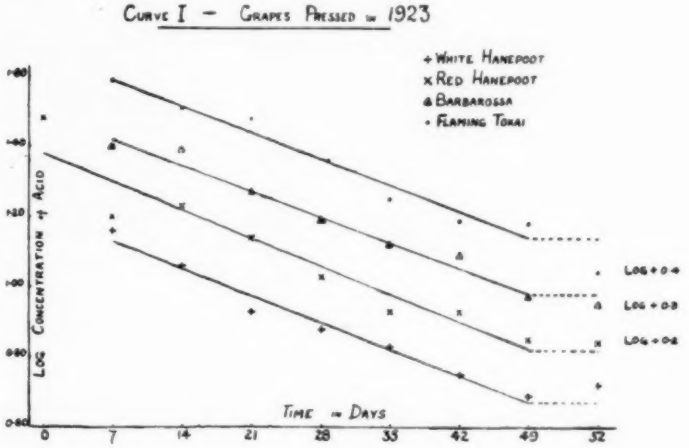
Acidity as Grammes of Tartaric Acid per 1000 *c.c. Juice.*

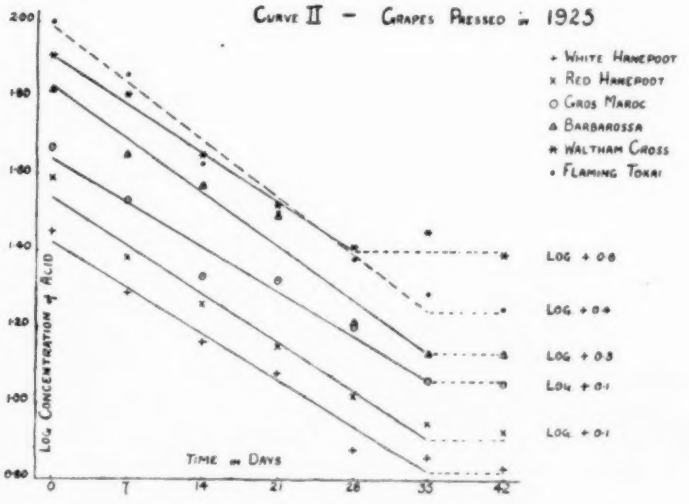
Date.	Days.	White Hanepoot.	Red Hanepoot.	Gros Maroc.	Barbarossa.	Waltham Cross.	Flaming Tokai.
28.1.25	0	28·1	31·0	37·2	33·1	20·4	40·2
4.2.25	7	19·3	19·1	26·8	22·5	16·1	28·8
11.2.25	14	14·5	14·5	17·1	18·4	11·1	16·9
18.2.25	21	12·0	11·3	16·7	15·3	8·3	12·5
25.2.25	28	7·6	8·4	12·5	8·1	6·4	9·6
4.3.25	35	7·3	7·0	9·1	6·7	7·0	7·7
11.3.25	42	6·8	6·7	9·0	6·7	6·2	7·0

When the logarithms of the concentration are plotted against the time, a straight line is obtained as shown in Curves I. and II. Therefore the changes in acidity may be expressed by means of the curve

$$\log C = a - bt.$$

It was found, however, that if the last reading were neglected, when the constants of the equation were calculated from the data, much closer





agreement was obtained between the observed and calculated readings. In the case of Waltham Cross the last two readings have been neglected in the

calculation. The most suitable curves have been calculated by the method of least squares and the following results obtained :—

1923—

White Hanepoot . .	log C=1·127—·011 *t*.
Red Hanepoot . . .	„ =1·180—·011 *t*.
Barbarossa . . .	„ =1·123—·010 *t*.
Flaming Tokai . . .	„ =1·195—·011 *t*.

1925—

White Hanepoot . .	log C=1·422—·017 *t*.
Red Hanepoot . . .	„ =1·441—·018 *t*.
Gros Maroc . . .	„ =1·542—·017 *t*.
Barbarossa . . .	„ =1·530—·020 *t*.
Waltham Cross . . .	„ =1·311—·018 *t*.
Flaming Tokai . . .	„ =1·585—·021 *t*.

The lines given in the curves have been plotted from the above equations. It is clear that the agreement is very close, and it may be regarded as certain that the change in acidity during the period of observation may be expressed by means of a logarithmic function. Under these circumstances the concentration of acid must vary with the time, and the rate of decrease in acidity must be proportional to the existing concentration.

Therefore

$$C=ke^{-bt}$$

$$\frac{dc}{dt}=-bc.$$

The constant "*a*" in the equations represents the value of the logarithm of the acidity at the time at which the experiments were commenced. On comparing the values of "*a*" in each set among themselves, it is seen that this constant differs according to the variety of grape, and therefore the acidity at any given time depends upon the variety of grape. The value of "*a*" in 1923 was lower than in 1925, indicating a probable seasonal variation.

The constant "*b*" measures the rate at which the acidity declines. When the values of "*b*" for individual varieties in each set are compared, it is seen that this value is practically independent of the variety of grape. The value for 1923 (about ·01), however, differed materially from the value (about ·02) for 1925. This again suggests that the decrease in acidity is dependent upon the season. Since the decrease in acidity of grapes is closely related to the ripening of the fruit, it seems clear that the rate at

which the fruit ripens depends upon some seasonal variation. At the same time it would appear that the rate of ripening during any season is independent of the variety of grape.

On examination of the curves it is seen that the lines lie very close to the mean position of the points in every case until the end of the period, when the calculated slope becomes too steep and the curve begins to flatten out. At this stage the decrease in acidity becomes negligible and the acidity remains very nearly constant. On further comparison it was found that this stage corresponded with the time at which the fruit could be regarded as ripe. Therefore at maturity it would appear that there is little or no further decrease in acidity. This is particularly noticeable in the case of Waltham Cross, in which the stage of maturity was reached about a week earlier than in the case of the remaining varieties.

Division of Chemistry,
Cape Town.

NOTE ON THE SOUTH AFRICAN MARINE MUSSEL *MYTILUS MERIDIONALIS* KRAUSS (1848).

By D. B. Swart.

(Communicated by Dr C. von Bonde.)

(With 3 figures in the Text.)

Introduction.

The object of this paper is to clear the confusion which seems to have arisen with regard to the specific characters of the South African marine mussel. Krauss, in 1848, in a work entitled Die Sudafrikanischen Mollusken, gives a full description of the shells and their markings, both externally and internally, of the South African marine mussel, and accordingly made it a distinct species—*Mytilus meridionalis*. His reasons for so doing are clearly indicated and appear well founded. Sowerby, without stating any reason, did not regard *meridionalis* as specifically distinct from *edulis*, and he, therefore, in his South African list, degraded *meridionalis* to a variety of *edulis*. Quite recently again, for an unstated reason, Tomlin reverted to Krauss's original arrangement, and there the matter seems to have ended. However, such a state of affairs is wholly unsatisfactory, more so since the reasons for these changes do not seem to have been given by either Sowerby or Tomlin.

Recently (1921–1922) a paper entitled " Biology and Economic Value of the Sea Mussel, *Mytilus edulis*," by Irving A. Field, was published in America, and there is no doubt in my mind that the differences between Krauss's *M. meridionalis* and the *M. edulis* described by Field are so varied as to render Sowerby's degrading invalid. Not only are the differences numerous, but some of them are of such a fundamental nature that, in creating a new species, Krauss seems to have been fully justified. He attaches much importance to the number and form of the hinge teeth, the muscle impressions, and the absence of pores in the white line under the ligament, and on those grounds alone, besides other variations, distinguishes his *M. meridionalis* from *M. edulis* and such forms as *M. angulatus* and *M. violaceus* Lamarck.

With regard to the two last named, it would be well here to give a short account of the confusion which arose out of the indiscriminate specification by Linne, Gmelin, and Lamarck of apparently similar forms occurring in different parts of the world. Linne, in the Museum Lud. Ulric reg. Suec., pag. 541, and in the 12th edition of his Syst. Natur., pag. 1157, has described a *M. angulatus* which he states as occurring in Southern Europe and at the Cape. As Krauss remarks, a comparison of his descriptions with the accompanying figures makes it evident that he wishes this species to include different mussels. Gmelin, pag. 3354, Nr. 12, has gone further, and includes a New Zealand *Mytilus* with many teeth as a variety; and Lamarck, to make the confusion greater, described another *M. angulatus*, thus bringing the total of species, which could bear the same name of *M. angulatus*, up to three. Krauss, on the other hand, is careful to state that the Cape edible mussel completely agrees with specimens which Professor Philippi sent him from Chili, and that Lamarck most probably includes the South American with his *M. angulatus*, which, on account of its unfortunately short description, may equally well include his (Krauss's). This unfortunate chaos Krauss wisely obviated by abandoning that name and creating the new one of *M. meridionalis*.

He also mentions a resemblance in shape to shells described by Gualtieri, tab. 91, fig. E (two large shells), and by Chemnitz, vol. viii, tab. 84, fig. 756. However, he adds that no great weight should be attached to form, as he observed in the case of his own specimens, but rather to the three previously mentioned characteristics, which are not quite clearly shown in the above-named figures. Further, he expresses doubt as to the identity of these with his species, especially because of several mussels under the name of *M. violaceus* in the K. Nat. Kabinet of Stuttgart which have a similar form but several small hinge teeth and many pores in the white line under the ligament, and adds that, according to form and size, the large specimens of *M. edulis* L., which were found in the Arsenal Canal at Venice, and of which Mr v. Martens procured a giant specimen of 4″ 4‴ long, 2″ 2‴ high, and 1″ 6‴ broad, could also be included here.

Finally, Krauss closes his analysis based on the hinge teeth and the ligament by declaring that the edible mussels from the Baltic and the North Sea, the Mediterranean and the Adriatic Seas, and even those from Chili and New Holland, all bear the same characters, but are smaller, narrow, in the adult condition more convex, and have usually a blunt umbo. He even asserts that those from Chili agree entirely with those from Trieste, and the New Zealand ones with those from the Baltic. According to him, all these, even *M. edulis*, as well as those described as *M. violaceus*, are distinguishable because of the presence of pores in the white line under the ligament, and still further from *M. meridionalis* in that they have in

the neighbourhood of the umbo two muscle impressions, one of which, very deep in the angle almost beneath the hinge teeth, is entirely wanting in *meridionalis*; the other, smaller and situated at the side of the anterior end of the ligament, is present in all, including *meridionalis*; and although Krauss owns that he could not find a corresponding muscle, the small impression anterior to the one at the side of the ligament certainly is distinctive of *meridionalis* and deserves the prominence given it by him.

Thus it would appear that Krauss has brought forward sufficient proof to admit of the specific distinctness of the Cape edible mussel. In view of my own knowledge intimately acquired in the laboratory over a period of several years, in addition to recent thorough investigation, I am not only able to verify Krauss's findings, but can also supply additional evidence which, to my mind, establishes *M. meridionalis* beyond all doubt as a distinct species.

The Shells.

Description (Krauss).

Krauss describes the shells as generally of an oblong oviform shape, and differentiates two types, basing his observations on an examination of twenty shells. He distinguishes between a broad and a narrow form, and states that the broad form is more common, having always a convex ventral margin and a blunt dorsal angle behind the ligament, the ratio of the length, height, and breadth being as 3·3 : 1·5 : 1. The narrow form is generally somewhat thick-shelled, has a straight, seldom concave ventral margin, and no dorsal angle behind the ligament, the dorsal margin from the umbo to the ventral margin being in the form of a uniformly undulated curve, and the ratio of the length, height, and breadth as 3·4 : 1·6 : 1. The dorsal angle referred to by him is the summit of the uneven, bow-like curve extending between the umbo and the posterior limit of the ventral margin. It is situated immediately behind the ligament which extends between it and the umbo in front. According to him, the shells, in comparison with those of *M. edulis* and those of related species, are very feebly convex and strongly flattened posteriorly. Otherwise, with the exception of these two comparisons, he is not too clear as to the general form of the shells; but in justice to him I can only reiterate and confirm his statement that one must not attach too great weight to the form. With regard to the exterior, he observes that the surface is more or less ribbed by lines of growth, shiny, frequently transversely striated on the anterior part of the ventral margin and the periostracum, brownish green in colour. The hinge line is steep and ventrally is slightly bent downwards. The hinge itself is narrow and provided with one or two teeth, concerning which Krauss

states that, in comparing his twenty specimens, he was able to find two kinds of tooth formation, and hardly two whose teeth were alike.

His differentiation of the tooth formation into two kinds he co-ordinates with that of the shells into broad and narrow forms, or, to use his own words, "the one occurs usually in broad mussels and shows in the left shell a more or less strong tooth which fits into the groove lying between two teeth in the right shell. The tooth of the left, however, sometimes lies in the middle, and then those in the right are equally large and regular; sometimes more towards the ligament, and then the lower tooth of the right is stronger and fits into the left shell. The other occurs chiefly in narrower forms, and shows in both shells two ridge-like teeth with a deep groove in the middle. In both forms there are very many variations and transitions." When it is borne in mind that his conclusions were drawn from an examination of only twenty specimens, this last statement detracts from the value of his differential tooth diagnosis, but fortunately leaves the bidentate condition as a specific character intact.

With regard to the thickness of the shells, he appends a footnote to the effect that this depends on the conditions under which the individuals live: if on rocks exposed to the surf, they are thick-shelled; if in the back-waters and away from the poundings of the waves, they are thin-shelled.

These in the main are the conclusions drawn by Krauss from an examination of only twenty specimens, and which it will be my endeavour to modify or elaborate in so far as it is possible to arrive at any definite formula where the external form and shape of the shells are concerned.

Form.—It seems strange that Krauss should express his conviction that no great weight must be attached to the form, and should, almost in the same breath, proceed, on the evidence of twenty specimens, to distinguish between a broad and a narrow form. However, it must be borne in mind that the fewer the specimens examined the more definite do the individual differences become and the easier it is to differentiate between such differences. Thus is Krauss's procedure explained. To him three main differences were patent on the examination of those twenty specimens, namely:

(1) Some presented a convex ventral margin; some a straight, seldom concave margin.

(2) Those with a convex margin had a blunt dorsal angle behind the ligament; those with the straight margin had no dorsal angle.

(3) Those with a blunt dorsal angle and a convex ventral margin were broader than those with no dorsal angle and a straight, seldom concave ventral margin, the ratio, according to him, of the breadth, height, and length being as 1 : 1·5 : 3·3 in the broad and as 1 : 1·6 : 3·4 in the narrow forms.

In his separation of the specimens into broad and narrow forms, Krauss was still further encouraged on examining the hinge teeth. He found that a more or less strong tooth in the left shell is typical of the broad forms, and two ridge-like teeth with a deep groove in the middle in both shells typical of the narrow forms. His statement, that in both forms there are very many variations and transitions between the two kinds of tooth formation, greatly minimises the importance of such a separation.

An examination of innumerable specimens from various localities along our coasts has revealed to me that no hard-and-fast rule as proposed by Krauss can be formulated to serve as a differential basis. As many mussels as were examined so many individual differences were presented, proving that the greater the number of specimens the less definite do the individual differences become and the more difficult it is to differentiate between such differences, the one merging into the other, and two apparently extreme types being reconcilable by intermediate merging individuals.

It was observed :

1. (*a*) That within a group of specimens with a well-marked dorsal angle, the ventral margin varies from extreme convexity to extreme concavity, all the intermediate stages for such a passage being represented within the group, *i.e.* the ventral margin may be convex, convexo-concave, straight, concavo-convex, or concave.

(*b*) That the same applies to a group of specimens with no dorsal angle.

2. (*a*) That within a group of specimens with a definite convex ventral margin, the dorsal angle varies from least obtuseness to excessive obtuseness or complete absence, all the intermediate stages for such an increase of the angle being represented within the group.

(*b*) That the same applies to a group of specimens with a well-marked concave ventral margin.

Krauss associates a convex ventral margin with a dorsal angle and a concave margin with absence of angle, and one is led to suppose that the paucity of his specimens is responsible for the lack of intermediate forms. Furthermore, granting that broad and narrow forms can be distinguished, the differences between the ratios of breadth, height, and length in these two types are hardly sufficiently emphatic to warrant a separation on the basis proposed by him.

3. That without exception the bidentate condition is characteristic of the species, but in no two specimens are the teeth alike, there being apparently as many varieties of tooth formation as there are specimens. Three distinct types, however, can be distinguished, namely :

A. One in which a single strong tooth occurs in the left shell, and fits into a groove between two less prominent teeth in the right shell.

B. Another in which a single strong tooth occurs in the right shell, and fits into a groove between two less prominent teeth in the left shell.

C. A third in which two equally developed ridge-like teeth with a deep groove in the middle occur in both right and left shells.

While the *C*-formation is more or less stable, the *A*- and *B*-formations present each three variations, according to the position of the single tooth.

In *A*-formation the single tooth in the left shell may lie :

(i) In the middle, with two equally deep grooves on either side, and then the teeth in the right are equally large and regular.

(ii) Toward the ligament, resulting in the flanking grooves being unequal, that near the ventral margin being wider and deeper than that near the ligament, and then the lower tooth of the right shell is stronger and fits into the lower groove in the left shell.

(iii) Toward the ventral margin, the flanking grooves also being unequal ; but here the groove near the ligament is wider and deeper than that near the ventral margin, and then the upper tooth of the right shell is stronger and fits into the upper groove in the left shell.

In the *B*-formation similar variations occur, the positions of the shells merely being reversed.

The *A*-formation is the most common, the *B*-formation less common, and the *C*-formation comparatively rare. One can only surmise that by chance in Krauss's twenty specimens the *C*-formation must have been equally well represented along with the *A*-formation, and the *B*-formation must have been entirely wanting.

Now it should be obvious that, between the three variations presented by *A* and *B*, all grades and stages of single-tooth migration from the ligament to the ventral margin, whether in *A* or in *B*, are liable to occur. Such a migration would result in an equal number of grades and stages of the two teeth in the opposite shell being brought about. Therefore, as has been stated before, there are as many varieties of tooth formation as there are specimens. However, as a specific diagnostic character, the bidentate condition throughout remains undisturbed, either one or the other or both shells showing two, and never more than two, ridge-like teeth.

External.—To give a general description which should embrace all the variations which the dorsal angle and the ventral margin are liable to assume, is obviously no light task. However, the external form should merely serve as a rough guide to the specific identity of the animal, and not as a basis for its specific classification.

M. meridionalis may be described as having generally an oblong sub-oval form, laterally compressed, the dorsal and ventral margins meeting acutely at the umbo, which is slightly bent downwards. The anterior dorsal margin which marks the hinge line is never straight, but always slightly convex ;

the posterior dorsal margin is roundly curved or undulate; the ventral margin is evenly convex, straight, slightly concave or undulate; the dorsal angle is obtuse, barely distinct or absent. At the umbo the antero-dorsal margin forms with the ventral margin an angle of about 45 degrees. The hinge line, flanked on either side by the anterior dorsal margins, is about half the length of the animal measured from the umbo to the posterior dorsal margin, and the ratio of the breadth, height, and length may vary in large specimens from 1 : 1·54 : 3·27 to 1 : 1·58 : 3·41; in small specimens the ratio may reach a minimum of 1 : 1·75 : 2·75, and with increase in size the growth in length and in breadth is proportionately more rapid than in height. From the broadest part of the animal the slope towards the dorsal angle is less steep than that towards the ventral margin, and posteriorly the shells are strongly flattened. The broadest part of the animal is at a point distant about one-third the length of the animal from the umbo, and about one-third its height from the ventral margin.

The colour is usually violet-black, occasionally violet-brown. The surface is corrugated with lines of growth concentric with the umbo, which is white terminally. The dried shells usually assume a brownish tint, due mainly to the horn-like sheath or periostracum, which itself is brown. The violet-black (rarely violet-brown) effect is brought about by a combination of the colours of the thin periostracum and the underlying prismatic layer, which contains a blue pigment. The different shades of colour, therefore, depend on the thickness and density of the ensheathing periostracum, and also, of course, on the intensity of the pigmentation in the prismatic layer.

Internal.—The inner surface of the shell is sharply divided into two areas by a demarcating line which may be even or serrated. The two areas are well contrasted, the inner being bluish white and the outer deep blue in colour. The outer, known as the pallial margin, is a long, narrow impression more or less one-quarter of an inch wide, and serves for the attachment of the pallial muscles. It extends from the depression under the hinge teeth along the ventral, the posterior, and the posterior dorsal edge to end under the posterior end of the ligament at a point distant about one-fifth the length of the ligament from its posterior end. From the posterior end of the ventral edge to its termination under the ligament the pallial margin is nearly twice as wide as along the ventral edge. The pallial line, *i.e.* the even or serrated line of demarcation between the two areas, has a slight dent or concavity behind and below the posterior adductor muscle impression. This concavity or pallial sinus is absent in related species, and is, therefore, a specific character, as pointed out by Krauss. Except for a distance about four-fifths the length of the ligament, the inner bluish white area is completely enclosed by the outer pallial margin, and in the

postero-ventral region is characterised by scattered punctations. These punctations are merely points of attachment of the epithelial cells of the outer surface of the mantle, and in the region near the inhalent siphon seem to be better marked than elsewhere.

1. *Anterior Retractor Impression.*—At the side of the ligament, at a point distant more or less one-third the length of the ligament from its anterior end, a small oblong oval impression is situated. Its distance from the ligament itself may often be less, but hardly ever more, than the length of its own shortest axis, *i.e.* its width. This impression marks the area of insertion of the *Anterior Retractor Muscle.*

2. *Oral Contractor Impression* (*?*).—Anterior to the anterior retractor, but further from the ligament, and more often than not about midway between and in a line with the anterior point of the umbo and the anterior retractor, is a much smaller and almost circular impression. Krauss mentions the occurrence of a similar impression in all his specimens, but states that he could not find, in specimens preserved in spirits, a muscle corresponding to it. It seems probable that his failure could be ascribed to the preservation of the specimens, for only in fresh specimens has it been possible to find a muscle corresponding to this impression, and then only when extreme care is exercised in the removal of the mantle. The muscle is very slender, and when once it is torn from its attachment to the shell, withdraws within the tissues of the labial palp whence it arises, all trace of it being subsequently lost.

3. *Posterior Adductor Impression.*—The largest and most prominent impression is that of the posterior adductor muscle. It is situated opposite the middle of the posterior border, its outer edge concurrent with the pallial line immediately above the pallial sinus.

4. *Dorsal and Posterior Retractors.*—From the dorsal edge of the posterior adductor impression another narrow impression extends anteriorly to end at a point opposite the posterior end of the ligament. However, it may be continuous or interrupted in different specimens, and in the latter case the break is usually at a point distant two-thirds the length of the impression from its anterior end.

(1) When the impression is continuous the muscles which arise in the foot are inserted side by side, and are called the *Posterior Retractors* of the foot.

(2) When the impression is interrupted, however, three (sometimes four) of the muscles are attached side by side, but one (always one) is some distance removed and attached above and adjacent to the posterior adductor muscle. In this case the latter is termed the *Posterior Retractor* and the anterior three (or four) the *Dorsal Retractors*, the impressions being termed likewise.

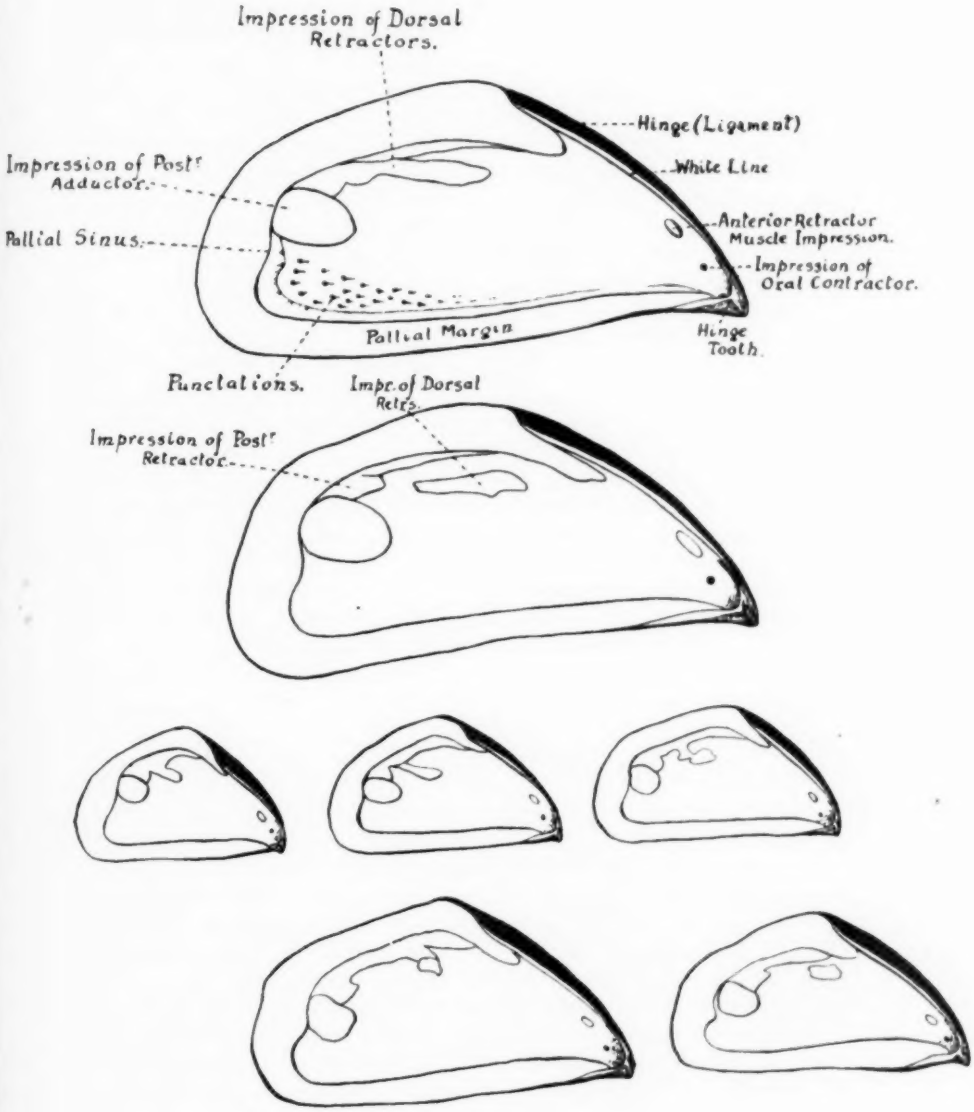

Impression of Dorsal Retractors.
Hinge (Ligament)
White Line
Impression of Post^r Adductor.
Pallial Sinus.
Anterior Retractor Muscle Impression.
Impression of Oral Contractor.
Pallial Margin
Hinge Tooth.
Punctations.
Impr. of Dorsal Retr^s.
Impression of Post^r Retractor.

FIG. 1.

5. *The Ligament.*—The ligament is almost half the length of the shell. It is very slightly and evenly convex, and extends from the umbo to the dorsal angle along the anterior dorsal margin. The ligament forms a cleft between the two shells, and in the absence of the dorsal angle the posterior end of the ligament is marked by the close approximation of the shells to close the cleft. Immediately under it is the characteristic white line which here is peculiar in that it exhibits a total absence of pores.

6. *The Hinge.*—The hinge is bent sharply downwards and may carry one prominent tooth, or two even, ridge-like teeth or two unequal teeth, but, no matter what variations they may present, never more than two teeth ever occur.

N.B.—There is no trace here whatsoever of either an anterior adductor muscle or its impression in the shell.

In brief, the specific characters of *M. meridionalis* may be summarised thus :

(1) At least one hinge tooth, but never more than two, is present irrespective of the position of the shells.

(2) Two muscle impressions at the side of the ligament and in a line with the umbo : (*a*) the most anterior almost circular and smaller than (*b*), which is oblong and oval and placed nearer the ligament.

(3) A distinct concavity or pallial sinus in the pallial line behind and below the posterior adductor impression and opposite the posterior edge of the shell.

(4) Total absence of pores in the white line under the ligament.

(5) No trace whatsoever of an anterior adductor impression ventral to the hinge.

Internal Structure.

As recently as 1922 the general structure of the South African marine mussel was described in a " Practical Zoology " for Medical and Junior Students, by Gilchrist and von Bonde of the University of Cape Town. Unfortunately, through some misunderstanding, although its identity with *M. edulis* was doubted, it was allowed to appear under that name. Reference to the " Biology and Economic Value of the Sea Mussel, *Mytilus edulis*," by Irving A. Field, and published in America in 1922, reveals several profound anatomical differences between the South African mussel and *M. edulis*. These differences, in conjunction with those between the shells, allow no justification for Sowerby's degrading of the South African marine mussel to a variety of *M. edulis*, but certainly serve to enhance the validity of its creation by Krauss as a new species under the name of *M. meridionalis*.

In view of the exhaustive nature of the two works quoted above, it is

proposed to deal merely with the main anatomical differences between *edulis* and *meridionalis*, rather than to give a detailed description of the latter.

1. *The Oral Contractor* (?).—This muscle, occurring for the first time in *meridoinalis*, is entirely wanting in *edulis*. It is of grave significance, and its shell impression, anterior to that of the anterior retractor of the foot, is included among the diagnostic specific characters of the former. It arises from the outer border of the proximal end of the upper labial palp of each side, where each of the latter is confluent with the sides of the mouth. It obviously serves the purpose of opening and closing the mouth by relaxing and contracting respectively, and is supplied by a nerve which arises from the cerebral ganglion, along with the anterior pallial nerve with which it is confluent for some distance, and then separates to run the length of the muscle to its insertion in the shell. It is proposed, therefore, to name the muscle the Oral Contractor and its impression the Oral Contractor Impression.

2. *The Anterior Adductor Muscle.*—This muscle, which is so well marked at the anterior end along the ventral margin in *edulis*, and the impression of which is distinct on the shell in that position, is wholly absent in *meridionalis*. Its absence, therefore, is useful as a negative character in determining the identity of the animal.

3. *The Stomach and Its Appendages—Alimentary Tract*—(a) *In M. edulis.*—According to Field, "the labial palps arise as a prolongation of the lips on both sides of the mouth, forming a two-paired organ, which is so situated that the upper pair lie externally to the lower pair when they are in normal position. They are, therefore, distinguished as outer and inner labial palps. The angle which is formed between the palps at their point of origin in each side marks the anterior termination of the gills and the position of the pigmented eye-spots. In form the palps are long, smooth, triangular bands marked on the median side with transverse ridges which extend from the middle to the ventral edge of each palp. A single longitudinal ridge runs from the corner of the mouth to the tip of each palp and forms the line of demarcation between the smooth and the ridged side. The inner palps are much broader at the base than are the outer ones, and are continuous with the lower lip on their ridged side, while the smooth side is attached to the surface of the liver. The outer palps are continuous with the upper lips on their ridged side and attached to the inner wall of the mantle with the opposite side." From this side there arises the very slender oral contractor muscle which, running outward and forward, pierces the adjacent mantle wall and is attached to the shell at the small, almost circular, impression in front of the impression of the anterior retractor muscle.

" The oesophagus arises directly at the mouth-opening, and continues backward and upward, bending off slightly to the right of the median plane to enter the anterior end of the stomach.

" The stomach is a small sac of irregular form, usually more or less

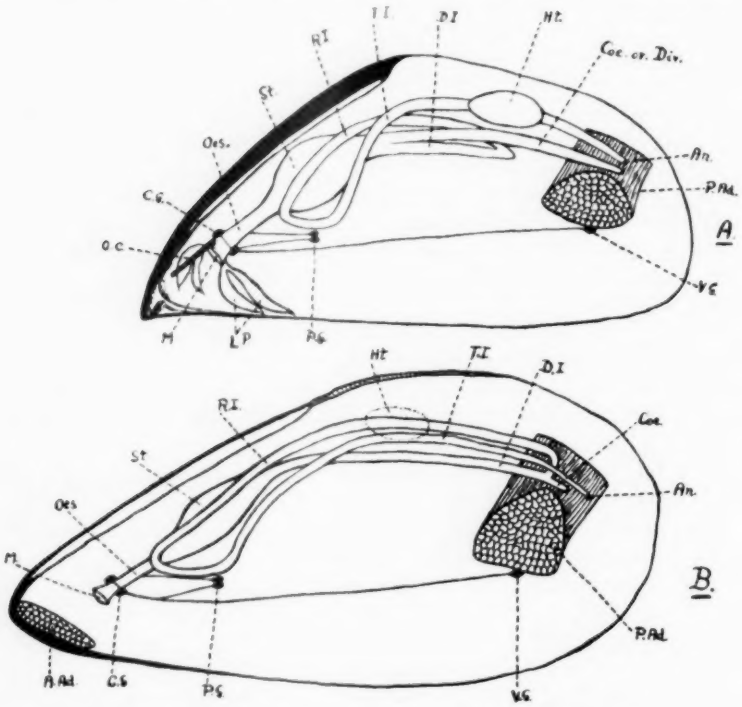


FIG. 2.—Alimentary Tract in A, *M. meridionalis*; B, *M. edulis*.

A.Ad., Anterior adductor; *An.*, anus; *Coe.* or *Div.*, coecum or diverticulum; *C.G.*, cerebral ganglion; *D.I.*, direct intestine; *Ht.*, heart; *L.P.*, labial palps; *M.*, mouth; *O.C.*, oral contractor; *Oes.*, oesophagus; *P.Ad.*, posterior adductor; *P.G.*, pedal ganglion; *R.I.*, recurrent intestine; *St.*, stomach; *T.I.*, terminal intestine; *V.G.*, visceral ganglion.

elliptical, with small pockets sometimes present in the dorsal, lateral, or ventral walls. It is situated dorsally just below the middle region of the hinge ligament, and lies chiefly on the right side of the body, completely surrounded by the liver tissue. Numerous large canals open into the stomach from the liver.

" The direct intestine arises from the posterior end of the stomach and

passes backward almost in the mid-line, except in its posterior third, where it bends slightly to the left side and terminates in a blind sac or coecum of the crystalline style on the dorsal surface of the posterior adductor muscle. When the animal is well-nourished the direct intestine is almost filled with a transparent, gelatinous rod which extends its whole length from the stomach to the coecum.

"The recurrent intestine arises from the median side of the direct intestine at the point where it crosses the mid-dorsal region of the posterior adductor muscle. It runs transversely for a short distance to the right side of the animal, and then turns directly forward to run parallel with the direct intestine as far as the posterior end of the stomach; at this point it bends gradually to the left, passing over the direct intestine and then downward and forward over the left side of the stomach almost to its anterior end, where the intestine suddenly makes a posterior loop. This bend marks the beginning of the terminal intestine.

"The terminal intestine, or rectum, as it is sometimes called, runs backward a short distance from its point of origin, parallel and almost in contact with the left anterior retractor muscle of the byssus, then it turns obliquely upward to the anterior end of the pericardial chamber. At this point it turns backward and passes directly through the ventricle of the heart, continuing on in the mid-line over the posterior adductor muscle, and terminating in an anus surrounded by dark brown pigmented epithelium, situated on the posterior surface of the muscle.

"In a mussel 80 mm. long, the mouth-opening has a width of 7 mm., the oesophagus a length of 12 mm., the stomach 13 mm., the direct intestine 32 mm., the recurrent intestine 48 mm., and the terminal intestine 52 mm."

(b) *In M. meridionalis.*—Here the description of the alimentary tract in *M. edulis* up to and including the stomach applies equally well. Where the intestine and coecum are concerned, however, extreme modification has taken place, as the following description will make clear.

N.B.—To facilitate matters, the names of the parts as employed by Field will also be used here.

The direct intestine arises from the posterior end of the stomach and passes backward in the middle line between the dorsal retractors. At a point opposite the middle of the dorsal retractors and the middle of the ventricle above it, the direct intestine bends sharply upon itself to the right and is known as the recurrent intestine.

The recurrent intestine follows a course backward to the right of and parallel to the direct intestine to a point opposite the origin of the latter in the stomach; thence it bends upward and forward and, turning gradually to the left, passes over the proximal end of the direct intestine, down

ward and forward over the left side of the stomach to its anterior end, where it suddenly makes a posterior loop.

This bend marks the beginning of the terminal intestine or rectum. For a short distance it runs parallel with and immediately above the left anterior retractor muscle of the foot. It then turns upward and curves slightly to the right, crosses over the proximal end of the direct intestine to enter the ventricle of the heart, which lies in the middle line. It passes directly through the ventricle, beyond which it continues in the middle line over the posterior adductor muscle, and terminates in the anus situated on the posterior surface of the muscle.

The coecum is much longer than that in *M. edulis*, and its origin from the direct intestine is also much further forward. It arises insensibly as a bifurcation of the dorsal region of the intestine a short distance behind the origin of the latter from the stomach, and midway between the posterior wall of the stomach and the dorsal retractor muscle. It passes backward under the floor of the pericardium, above the direct intestine, and slightly to the left of the rectum, to end blindly alongside the anus on the posterior surface of the posterior adductor muscle. From its inception to its termination the coecum is about twice as long as the direct intestine, and only that part of the direct intestine anterior to the origin of the coecum is filled with the gelatinous substance which extends throughout the entire length of the coecum, and is known as the crystalline style. The coecum is also known as the diverticulum, and is about six times as long as that in *M. edulis*.

4. *The Nervous System.*—The nervous system in *Mytilus* is a slight modification of the Lamellibranchiate type, consisting, as it does, of three pairs of ganglia connected by commissures, the entire system being uniformly bilateral. On either side of the oesophagus is a small cerebral or cerebro-pleural ganglion connected with its fellow of the opposite side by a cerebral commissure which passes above the oesophagus. From each cerebral ganglion a commissure passes backward and downward to a pedal ganglion situated at the apex of the angle formed by the two anterior retractor muscles, and is known as the cerebro-pedal connective. The two pedal ganglia are closely adherent along their adjacent borders, so much so, that they form a single bilobed mass. Another commissure—the cerebro-visceral connective—also leaves each cerebral ganglion and passes directly backward along the base of the gill to the visceral ganglion under the posterior adductor muscle. The two visceral ganglia are separated by a ridge of the mesosoma and are connected by a visceral commissure. Numerous smaller nerves lead off from these three main nerve centres, the cerebral or cerebro-pleural supplying the labial palps and the anterior part of the mantle; the pedal the foot and its muscles; the visceral the

alimentary tract, the heart, the gills, and the posterior portion of the mantle.

Whatever incongruities may be presented by the lesser nerves to the various organs are entirely eclipsed by the vagaries of the cerebro-pedal connectives in *meridionalis* as compared with their more or less typical arrangement in *edulis*.

(a) *In M. edulis.*—" The cerebral ganglia are triangular bodies which lie with their apices pointing backward on the ventral side of the oesophagus just under the posterior edge of the lower lip. They are laterally placed, so that in the adult mussel they are separated by a distance of 4–6 mm.

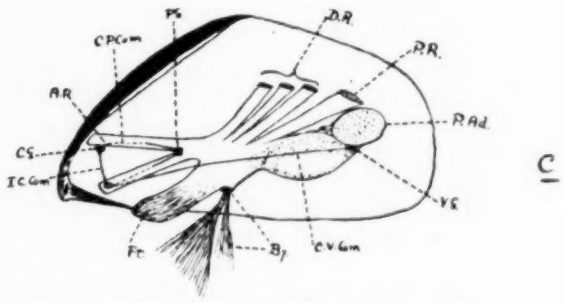


FIG. 3.—Muscles and Nervous System in C, *M. meridionalis*.

A.R., Anterior retractor; *By.*, byssus; *C.P.Com.*, cerebro-pedal commissure; *C.G.*, cerebral ganglion; *C.V.Com.*, cerebro-visceral commissure; *D.Rs.*, dorsal retractors; *Ft.*, foot; *I.C.Com.*, inter-cerebral commissure; *P.Ad.*, posterior adductor; *P.G.*, pedal ganglion; *P.R.*, posterior retractor; *V.G.*, visceral ganglion.

In some specimens they are very conspicuous to the naked eye, owing to the presence of an orange-red pigment, while in others they are difficult to find because the bright pigment is absent, and their colour is like that of the tissue in which they lie. The cerebral ganglia are united by the cerebral commissure, which runs dorsally over the oesophagus. Each ganglion gives rise to a large anterior trunk, the anterior pallial nerve, and a posterior trunk which contains the combined cerebro-visceral and cerebro-pedal nerves. Besides these there are two fine fibres, one of which supplies the labial palps and the other the eye.

" The cerebro-pedal and cerebro-visceral connectives leave the posterior angle of the cerebral ganglion in a common trunk that passes backward and outward across the ventral side of the anterior retractor muscle. When it reaches the lateral side of the muscle the trunk divides into two separate components. The cerebro-pedal connective continues backward and around the anterior retractor muscle to its dorsal wall, and terminates in the pedal

ganglion. The cerebro-visceral connective at the point of bifurcation with the cerebro-pedal connective turns upward and continues in a posterior direction across the lateral surfaces of the posterior retractor muscles to its point of termination in the visceral ganglion."

(b) *In M. meridionalis.*—(1) Here, however, each cerebral ganglion gives rise posteriorly to two separate trunks, an inner cerebro-pedal and an outer cerebro-visceral connective, and at no point along the extent of either is the one fused with the other. Moreover, whereas the separate cerebro-visceral connective passes straight backward around the outside of the anterior retractor muscle, the cerebro-pedal dives backward through that muscle, emerges on its dorsal wall, splitting the muscle bundle into two longitudinal halves, and terminates in the pedal ganglion situated at the apex of the angle formed by that muscle with its fellow. The two pedal ganglia are adherent, and it naturally follows that the two cerebro-pedal connectives form the sides of an isosceles triangle of which the inter-cerebral commissure is the base and the pedal ganglia the apex.

(2) The anterior pallial nerve in *meridionalis* gives rise to an additional branch a little distance from its origin at the cerebral ganglion. This branch at once enters the slender oral contractor muscle, and may conveniently be called the oral contractor nerve.

These, in brief, are the main anatomical differences between *edulis* and *meridionalis*, and, in addition to those variations in the shells as pointed out by Krauss and elaborated in this paper, are certainly of sufficient significance to dispel all doubts which may be entertained as regards the specific entity of *M. meridionalis*.

THREE NEW HELMINTHS.

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Veterinary Research Officer, Onderstepoort, Pretoria.

(With twelve Text-figures.)

Moniezia pallida n. sp.

On three previous occasions fragments of a *Moniezia* from the horse were received in tubes containing parasites collected from horses in South Africa. However, all these cases appeared rather doubtful, and no further notice was taken of them until recently, when my colleague, Dr. Veglia, kindly handed over to me a complete specimen which he had taken from a horse. On studying this specimen, it was found to be a new species, and it is consequently here described as *M. pallida* on account of the indistinct linear interproglottidal glands.

The worm has the general outward appearance of a *Moniezia*, measuring 138 cm. in length. The segments are all much broader than long and slightly overlapping; the mature segments are 0·75 mm. long and 11 mm. broad, the ripe segments are 1·5 mm. long and 21 mm. broad. The head is unarmed, but there are four well-developed suckers facing anteriorly; the head, as seen from the front, is not square but dorso-ventrally compressed, measuring 0·75 mm. in breadth. There is a well-developed neck (fig. 1).

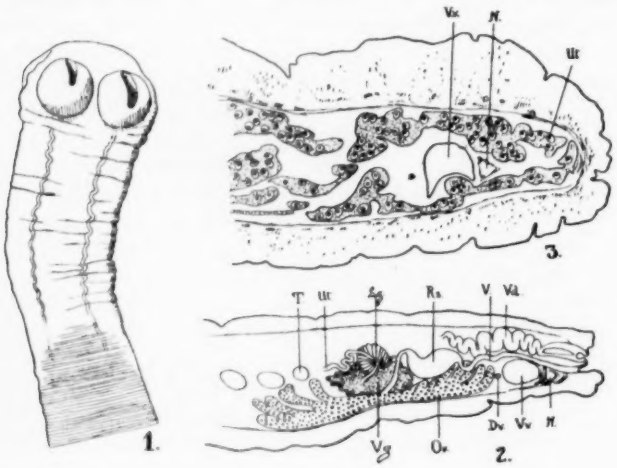
The interproglottidal glands are linear, *i.e.* of the *Planissima* type, but they are very indistinct in all stained specimens and sections; they are 1·1 mm. broad in mature segments and 2 mm. in ripe segments.

The cuticle is 8 μ thick; under it is a layer of subcuticular cells 19 μ wide. The longitudinal muscles are more or less diffuse, lying chiefly against the transverse layer. The latter, as well as the dorso-ventral muscles, are well developed.

The excretory system consists of the usual four longitudinal vessels and transverse branches. The dorsal vessel lies median to the ventral.

The genital pores are double, and there are two complete sets of reproductive organs in each proglottis. The genital pores open somewhat anterior to the middle of the proglottis. The genital ducts pass dorsally to the excretory vessels and the nerve; the vagina is ventral to the cirrus on the

right side and dorsal to it on the left. The testes occupy the whole of the median field, and there are also a few on the poral side of the ovary. The vas deferens makes several coils before entering the cirrus pouch and is distended with spermatozoa. The cirrus pouch reaches up to the ventral excretory duct and measures 0·23 mm. by 0·08 mm.; the cirrus is 0·13 mm. long by 0·04 mm. and is inerm. The vagina is slightly coiled and ends in a large receptaculum seminis. The ovary is fan-shaped, broader than long, finely lobed, measuring 1·06 mm. in breadth by 0·48 mm. in length. The yolk



FIGS. 1–3.

gland is well developed and is situated dorsally to the ovary. The oviduct joins the ovary directly in front of the yolk gland (fig. 2). The uterus is at first a reticulum of slender branches and occupies the whole of the median field, also extending across the lateral excretory ducts. When it is filled with eggs it occupies practically the whole of the medulla, its branches passing chiefly dorsally, but also quite frequently ventrally, to the longitudinal excretory ducts (fig. 3). In this point *M. pallida* differs from all other *Moniezias*, in which, according to Douthitt (1915), the uterus passes dorsally across the longitudinal excretory ducts or not at all. However, this difference, even coupled with the fact that the mammalian *Moniezias* are typically parasites of Ruminants, does not seem to me to justify the creation of a new genus, and I therefore prefer to leave it in the genus *Moniezia*.

Host.—*Equus caballus.*

Location.—Small intestine.

Locality.—Transvaal, South Africa.

Trichostrongylidae Leiper, 1912.

Trichostrongylinae Leiper, 1908.

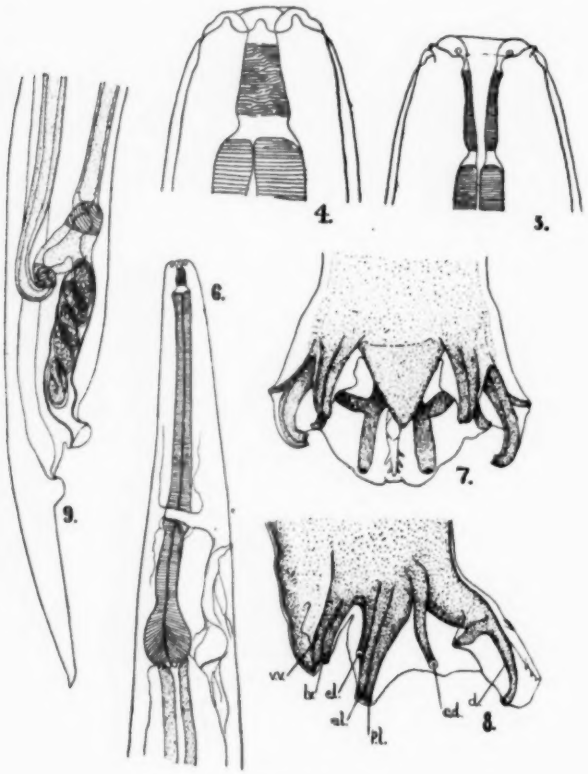
Spirostrongylus australis n. gen., n. sp.

The only Trichostrongylus so far known from the kangaroo is *Austrostrongylus macropodis* Chandler, 1924, from the small intestine of *Macropus Bennetti*. The second one, to be described in this paper, was found in the stomach of a Red Kangaroo, *Macropus rufus*, which died in the Pretoria Zoological Gardens shortly after it had been imported from Australia. This parasite belongs to the Trichostrongylinae, but has to be placed in a new genus, and I therefore propose to name it *Spirostrongylus australis* on account of its pharynx, which resembles that of some Spiruridae; in fact, under a low magnification, the pharynx presents very much the appearance of that of *Arduenna*.

The worms are straight, light pink or greyish in colour. They taper slightly towards both extremities. The cuticle is not striated. There are no cervical alae nor cervical papillae. The mouth opening is circular and is surrounded by six papillae, two lateral and four submedian. The mouth opening leads into a pharynx which is 0·08 mm. deep and is bounded by chitinous walls which are relatively thick and are made up of irregular transverse ridges. These ridges begin a short distance behind the mouth opening and stop a short distance before the beginning of the oesophagus (fig. 4). In a dorsal or ventral view the mouth appears to be surrounded by two lateral lips; this is due to the fact that the walls of the buccal cavity appear to be thicker laterally than they are on the dorsal and ventral sides, since the pharynx and the oesophagus anteriorly are laterally compressed (fig. 5). The oesophagus is fairly long and bears a slight swelling a short distance behind its middle, and ends in a strong bulb. The nerve ring is situated around the first swelling of the oesophagus, and the excretory pore opens ventrally a short distance behind the level of the nerve ring (fig. 6).

The male is 9·2 to 10 mm. long and 0·38 mm. thick. There is a well-developed bursa supported by the usual number of bursal rays, which all end in fairly conspicuous papillae. The ventral rays are equal, close together, and parallel. The externo-lateral is shorter than the medio- and postero-laterals and does not reach the edge of the bursa, but is turned outwards, *i.e.* lateral, lifting up the bursa to a prominent point (fig. 7). The medio- and postero-lateral rays are parallel, equal, and close together, their tips turning inwards. The externo-dorsal ray lies wholly within the lateral lobe and originates very high up from the base of the dorsal ray; it is thinner than the medio- and postero-laterals and reaches the edge of the bursa; its tip is turned outwards (fig. 8). The dorsal ray divides at about the middle of its length into two strong branches which are at once widely separated, and each

again gives off a lateral branch which passes off at right angles or is directed even slightly forward. Between the two branches of the dorsal lobe the bursa has a fold (or a thickening) which almost resembles a continuation of the dorsal ray, and in most specimens bears irregularly placed finger-like



FIGS. 4–9.

side-branches; this whole structure is transparent. There are a large number of minute papillae situated on the inner surface of the lateral and ventral lobes of the bursa. The genital cone is prominent and simple. There are two equal spicules, simple rods with each an ala on the medio-ventral side. At the points of the spicules the alae fuse, forming an oval membrane, in which the points of the spicules lie fixed together. The spicules measure 2·02 mm. in length. A gubernaculum is wanting.

The female is 12·5 mm. long and 0·5 mm. thick. The whole oesophagus is 1·17 mm. long, the bulb 0·13 mm. by 0·17 mm.; the nerve-ring is 0·77 mm. from the anterior end, and the excretory pore 0·84 mm. The head is 0·07 mm. broad, the pharynx is 0·076 mm. deep. The vulva is situated 0·15 mm. in front of the anus; it is prominent and leads into a vagina 0·52 mm. long, followed by a double ovijector which leads on each side into a uterus. The uteri are divergent, and their first portions, about 1·5 mm. long, are empty. The uteri and ovaries do not enter the first 3·8-mm. length of the body. The eggs are very large, measuring 175 μ by 77 μ, and contain a complete embryo when laid. The tail of the female is 0·56 mm. long, acute, and its end is slightly bent dorsad. The anus opens in front of a prominent swelling (fig. 9).

Host.—*Macropus rufus.*

Location.—Stomach.

Locality.—Pretoria Zoological Gardens, recently imported from Australia.

Genus.—*Spirostrongylus* n. gen.

Definition.—*Trichostrongylinae:* Body straight, not red, cuticle not striated. Mouth surrounded by six papillae and followed by a well-developed buccal cavity whose walls are strengthened by cuticular ridges. Oesophagus provided with a bulb. Male bursa well developed: the ventral rays are equal, close together, and parallel; the externo-lateral ray is short and does not reach the edge of the bursa; the medio- and postero-lateral rays are close together and parallel; the externo-dorsal ray lies in the lateral lobe and reaches the edge of the bursa; the dorsal ray divides into two strong branches, with each a lateral branch. Vulva posterior, uteri divergent. Ovoviviparous.

Type-species.—*S. australis* n. sp.

Filariidae Claus, 1885.

Filariinae Stiles, 1907.

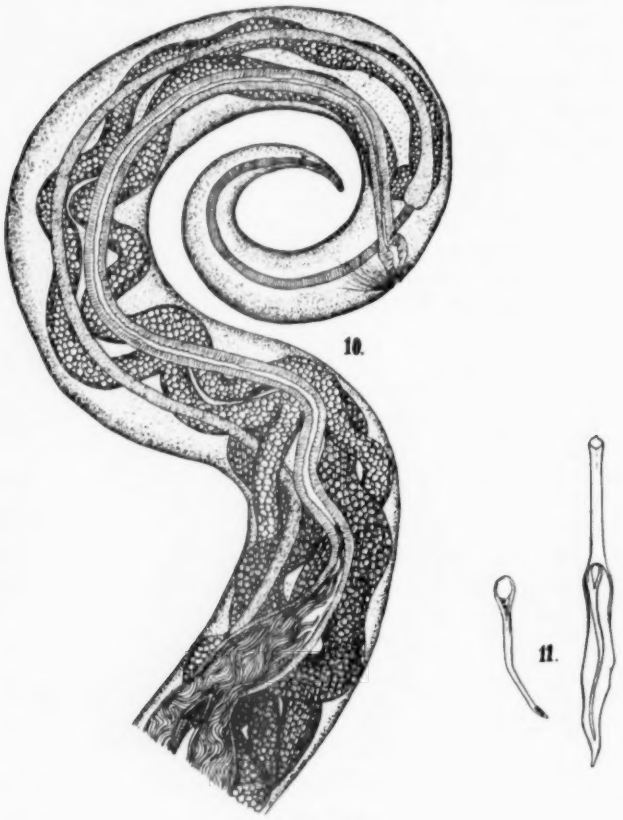
Cordophilus sagittus (v. Linstow, 1907).

Specimens of this worm have been found on various occasions as follows: free in the left ventricle of a koodoo (*Strepsiceros strepsiceros*), in the Transvaal; in a thrombus in the left ventricle of a bushbuck (*Tragelaphus sylvaticus*), collected by G. Purviss, M.R.C.V.S., in Kenya; in a myocardial tumour of an ox (*Bos taurus*), collected by Dr. A. Ayres in Portuguese East Africa; and again in the heart of a bushbuck, apparently free, collected at Iringa, Tanganyika Territory.

This parasite has been briefly described by von Linstow (1907) as *Filaria sagitta*, from the heart of a bushbuck, and was redescribed by Turner (1925) under the same name. In both cases only one pair of preanal and

one pair of postanal papillae are mentioned. For the reasons given below in the generic diagnosis, it seems to me that the worm cannot be left in the genus *Filaria*.

These are white, fairly thick worms, tapering slightly at the posterior



Figs. 10 and 11.

extremity, especially in the male, and very much anteriorly. The cuticle is not striated. The mouth opening is a circular pore, and the head is nude, except for a few papillae which are, however, very indistinct. The oesophagus is fairly long and consists of an anterior muscular and a posterior glandular portion.

Male, 57 mm. long, 0·73 mm. thick. The tail is narrow and spirally

coiled ; it is not provided with alae and ends bluntly. There are two pairs of preanal papillae and a very large unpaired one, which is situated a short distance in front of the anus (fig. 12). The postanal papillae are four pairs situated closely behind the anus ; the most anterior pair is placed just behind the lateral angles of the anal opening. A short distance behind these, and slightly more median, is a large pair of papillae, and between the latter almost on the posterior lip of the anus, runs a row of four small papillae, two on each side. There are two unequal spicules : the left is 0·5 mm. long, and its posterior part is almost wholly membranous ; the right is 0·2 mm. long ; it is more slender, and is bent at about its middle (fig. 11).

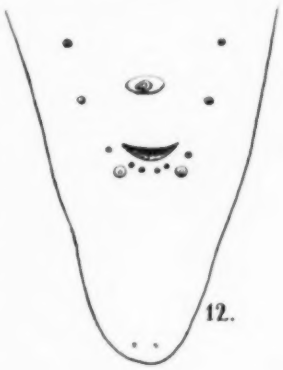


Fig. 12.

Female, up to 75 mm. long and 1·2 mm. thick. The head is 47 μ broad ; the muscular oesophagus is 0·4 mm. long and the glandular portion 2·5 mm. The intestine is a very narrow tube. The nerve-ring is situated around the middle of the muscular part of the oesophagus. The vulva opens 2·1 mm. from the anterior end and leads into a short vagina, which is provided with a strong S-shaped sphincter as found, *e.g.*, in *Habronema* (fig. 10). This is followed by a long ovijector, measuring 10·6 mm., which is at first narrow and finally widens out to form a reservoir joining two backwardly directed uteri. The latter make numerous windings forwards and backwards in the body, filling the body cavity, together with the ovaries from near the vagina to the tail. The latter is thick and blunt and bears the anus, which is a minute pore, very near to its end. The eggs measure 36 μ by 18 μ. Viviparous ; the larvae, which did not appear to be very well fixed, measure 0·33 mm. in length.

Host.—Cattle (*Bos taurus*), koodoo (*Strepsiceros strepsiceros*), and bush-buck (*Tragelaphus sylvaticus*).

Location.—Heart ; free in ventricle, in thrombus in ventricle, and in myocardial tumour.

Locality.—Transvaal ; Portuguese East Africa ; Iringa, Tanganyika Territory ; Kenya Colony.

Genus.—Cordophilus n. gen.

Definition.—Filariinae : Head nude, vulva anterior and provided with an S-shaped sphincter, two uteri. The male tail bears two pairs and one unpaired preanal papillae and four pairs of postanal papillae placed close

to the anus; two unequal spicules. Viviparous. Tail of female blunt, with anus almost terminal.

Type-species.—*C. sagittus* (v. Linstow, 1907).

EXPLANATION OF FIGURES.

Fig. 1. *Moniezia pallida* n. sp. Head, ventral view.

Fig. 2. *Moniezia pallida* n. sp. Compilation of several transverse sections through a mature proglottis, to show the relations of the genital organs on the right side.

Fig. 3. *Moniezia pallida* n. sp. Transverse section of a ripe proglottis, showing the uterine branches passing ventrally as well as dorsally to the longitudinal excretory vessels. Dv., dorsal vessel; N., nerve; Ov., ovary; Rs., receptaculum seminis; Sg., shell-gland; T., testis; Ut., uterus; V., vagina; Vd., vas deferens; Vg., vitelline gland; Vv., ventral vessel.

Fig. 4. *Spirostrongylus australis* n. gen., n. sp. Head, lateral view.
Fig. 5. ,, ,, ,, Head, dorsal view.
Fig. 6. ,, ,, ,, Anterior end, lateral view.
Fig. 7. ,, ,, ,, Male bursa, ventral view.
Fig. 8. ,, ,, ,, Male bursa, lateral view.
Fig. 9. ,, ,, ,, Hind end of female.
Fig. 10. *Cordophilus sagittus* (v. Linstow, 1907). Anterior end of female.
Fig. 11. ,, ,, ,, Male spicules.
Fig. 12. ,, ,, ,, Tail of male, ventral view.

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HADAMARD'S APPROXIMATION-THEOREM SINCE 1900.

By Sir Thomas Muir, F.R.S.

There are two rather important theorems in determinants which both bear Hadamard's name, one belonging to the year 1893 and the other to 1903. As confusion has arisen by each of them being called simply "Hadamard's theorem," I propose, as in the above title, to call the earlier of them his *approximation*-theorem and the later his *evanescence*-theorem. In doing so, however, I am also in duty bound to recall the fact that the former theorem has a claim to bear also Lord Kelvin's name, he having been occupied with it eight years in advance of Hadamard * ; and in connection with the latter to draw attention to the earlier results of Lévy (1881) and Desplanques (1886).

Nanson, E. J. (1901 /$_7$).

[A determinant inequality. Messenger of Math., xxxi, pp. 48–50.]

The inequality referred to is that communicated by Sir William Thomson (afterwards Lord Kelvin) to Muir in 1885 (Hist., iv, p. 32), namely, that *any determinant* $<\sigma_1 \sigma_2 \ldots \sigma_n$ *where* σ_r *is the square root of the sum of the squares of the elements of its* r^{th} *row.* Here it is first based on geometrical considerations, which in the case of the 3^{rd} order are (*a*) that if $(x_1y_1z_1)$, $(x_2y_2z_2)$, $(x_3y_3z_3)$ be the other extremities of three edges of a parallelopiped that meet in the origin, the volume of the parallelopiped (Hist., i, p. 348) is $|x_1y_2z_3|$; (*b*) that a parallelopiped whose edges are fixed in length is of greatest volume when the edges are mutually perpendicular. Next, the theorem is shown to be easily deducible from a property of a special axisymmetric determinant, namely, that *any positive axisymmetric determinant whose coaxial minors of every order are positive can never be greater than the product of its leading diagonal elements.* The deduction is possible because the square of any determinant is known to be such a special axisymmetric, having in fact any of its *r*-line coaxial minors expressible as the sum of $(n)_r$ squares. The author also does not fail to note that the square of an oblong array is such another, and he formulates the wider derived result.

* For a short statement of the related facts in regard to this, see Transac. R. Soc. S. Africa, I, p. 323, footnote.

FISCHER, E. (1907 $^1/_6$, 1908 $/_1$).

[Ueber den Hadamardschen Determinantensatz. Archiv d. Math. u. Phys., (3), xiii, pp. 32–40.]

Much of this is occupied with the consideration of Hermitian forms—that is to say, with quadrics of the type $\Sigma a_{ik} x_i \bar{x}_k$, where the a's and x's are complex and $\bar{x}_k$ is conjugate to x_k. Indeed, it appears to be considered that for the purposes of exposition a combination of the two subjects, the form and its determinant, is preferable; and half the paper is taken up in familiarising the reader with the inter-relations of the two, approved restatements of Hadamard's theorem and lemma being given with this end in view. The course thus taken is so far justified in that it leads to the establishment of an interesting generalisation of the said lemma, namely, *The determinant of every positive definite Hermitian form is not greater than the product of any coaxial minor and its complementary.* As an example of such a form, to which this and Hadamard's theorem are usefully applicable, there is brought forward the case where the coefficients a_{ik} are of the form

$$\int_a^b u_i(s) \cdot u_k(s) ds,$$

and where the u's are real or complex functions, continuous between the limits a and b, and the variable s is real and continuous. Lastly, connected with this determinant of definite integrals, we not unexpectedly come on the condition that the u's as above specified will be linearly independent if

$$\begin{vmatrix} \int_a^b u_1^2 ds & \int_a^b u_1 u_2 ds & \dots & \int_a^b u_1 u_n ds \\ \dots & \dots & \dots & \dots \\ \int_a^b u_n u_1 ds & \int_a^b u_n u_2 ds & \dots & \int_a^b u_n^2 ds \end{vmatrix} \leqslant 0,$$

and we are thus brought into touch with a rival of the Wronskian.

WIRTINGER, W. (1907 $/_7$).

[Zum Hadamardschen Determinantensatz. Monatshefte f. Math. u. Phys., xviii, pp. 158–160; or, in French, Bull. des Sci. Math., (2), xxxi, pp. 175–179.]

What Wirtinger gives us is a quite fresh proof. His mode of procedure is a direct application of the ordinary Lagrangian rule for finding by differentiation the extreme values of a function whose variables are connected by equations of condition. His remarks on the corresponding geometrical theorem coincide with those of Nanson in his paper of 1901 (see above, p. 299).

SHARPE, F. R. (1907 $/_{10}$).

[The maximum value of a determinant. Bull American Math. Soc., xiv, pp. 121–123.]

The subject here is those maximum determinants whose elements are either 1 or -1. Taking such a determinant of order $4p$ and value $(4p)^{2p}$ the author finds the values of its minors

of order $4p-1$ to be $(4p)^{2p-1}$ or $-(4p)^{2p-1}$,
. . . $4p-2$ . . . $2(4p)^{2p-2}$ or $-2(4p)^{2p-2}$ or 0.
. . . $4p-3$ . . . $4(4p)^{2p-2}$ or $-4(4p)^{2p-2}$ or 0.

Also by bordering it with the permissible elements he constructs a determinant

of order $4p+1$ whose value is $4(4p-1)(4p)^{2p-1}$.

By this means it is thought that possibly maximum determinants whose order is not a multiple of 4 may have been lit upon. In any case it is important to note that Davis' theorem of 1882 on the same subject (Hist., iv, p. 18) is shown to be quite unreliable. According to the latter the maximum determinant of the 7th order is the circulant C(−1, 1, 1, 1, 1, 1, 1), whose value is 320; whereas, as we now learn, a rival is ready to hand whose value is 512, namely, the cofactor of the $(1, 1)^{\text{th}}$ element in Hadamard's 8-line maximum determinant of 1893 (Hist., iv, pp. 483–484).

MUIR, T. (1908 $^{28}/_{12}$).

[An upper limit for the value of a determinant. Transac. R. Soc. S. Africa, I, pp. 323–334.]

Unlike the preceding writings the present deals not only with Hadamard's theorem specially so called, but with all the other contents of his paper of 1893. Naturally at the outset the writer recalls Lord Kelvin's theorem, which preceded Hadamard's and his own lemma by which Lord Kelvin's theorem was proved, namely, *If* s_r *be the square root of the sum of the squares of the elements of the* r^{th} *row of any determinant* D, *and* S_r *be the like square root in the case of the adjugate, then*

$$D \leqq s_r S_r.$$

He then not only extends his proof of 1885 (Hist., iv, p. 32) to cover Hadamard's more general theorem, using for the purpose the multiplication of a pair of special 2-by-n arrays, but gives an alternative proof that is also

purely determinantal, based on Chio's condensation-theorem. The conditions under which Hadamard's limit may be actually reached are next discussed, the circumstances under which a determinant may appropriately be spoken of as having a maximum value or of being a maximum determinant, and the cause of the close relation between such a determinant and the inversely orthogonal determinant (or ant-orthogonant) which Sylvester had studied in 1867 (Hist., iii, pp. 478–480). The main facts so brought out may be condensed thus: *If* δ, δ' *be determinants whose corresponding elements are conjugate complex, and* Δ, Δ' *be their respective adjugates, then* (1) *when the elements of* δ *are proportional to the corresponding elements of* Δ' *the value of* δ *is a maximum;* (2) *when in addition the elements of* δ *are equimodular* δ *is inversely orthogonal; and* (3) *when* δ *is inversely orthogonal and has equimodular elements its value is a maximum.* In support of Sylvester it is then proved that *the alternant of the* n^{th} *order* $|x^0y^1z^2w^3 \ldots|$ *will be inversely orthogonal if* x, y, z, w, . . . *be the* n^{th} *roots of a constant,* and, as a preparation for Hadamard, that *whatever* d *may be, the determinant*

$$\begin{vmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & d & -d \\ 1 & -1 & -d & d \end{vmatrix}$$

is inversely orthogonal, the product of any element by its cofactor in the determinant being $-4d$, *and therefore the value of the determinant itself* $-16d$. Regarding the formation of Hadamard's maximum determinants with unit elements it is shown (1) that *if a solution be obtained for order* r *it is easy to give a solution for order* 2r; (2) that *those of order* 2^m *are axisymmetric*; and (3) that *the one of order* 12 *is axisymmetric, but not the one of order* 20. Finally, maximum determinants with real elements other than unity are considered; like those just spoken of they are shown to be orthogonants, and examples are given that are also skew.

Schur, I. (1909 early).

[Ueber die charakteristischen Wurzeln einer linearen Substitution mit einer Anwendung auf die Theorie der Integralgleichungen. Math. Annalen, lxvi, pp. 488–510.]

In this paper Hadamard's theorem makes a merely incidental appearance (§ 5) as being included in a theorem on latent roots. The latter is in effect that *the sum of the norms of the latent roots of a determinant is not greater than the sum of the norms of the elements*; and the passage from it to Fredholm's case of Hadamard's theorem is easily effected by first using the

familiar inequality connecting the arithmetical and geometrical means in order to bring in the product of the norms instead of the sum, and then by substituting the determinant itself for the said product.

HAYASHI, T. (1909 /$_7$, 1910 /$_4$).

[Hadamard's theorem on the maximum value of a determinant. Tôkyô Sûgaku-Butur. Kizi, (2), v, pp. 104–109; also, in French, Giornale di Mat., xlviii, pp. 253–258.]

The writer here establishes the special case of Hadamard's theorem where the elements are all real and the sum of the squares of the elements of each row is 1. The mode of proof is similar to Muir's second mode as applied to the general theorem, being based on Chio's condensation result of 1853.

KOWALEWSKI, G. (1909).

[Einführung in die Determinantentheorie, ... v+550 pp., Leipzig.]

Kowalewski confines himself (pp. 458–460) to the case of Hadamard's theorem where the elements are real; and his mode of proof is not essentially different from the original of 1893, thus merely turning upon the fact that *the determinant which is the square of an* m-*by*-n *array of real elements is less than the product of its* (p, m)$^{\text{th}}$ *element by the cofactor of that element.*

TONELLI, L. (1909).

[Sul teorema di Hadamard relativo al valor maggiorante di un determinante. Giornale di Mat., xlvii, pp. 212–218.]

The theorem in question is here put in the specialised form used by Fredholm and spoken of above as Fredholm's case, namely, *If the absolute value of every element of an* n-*line determinant be less than a positive quantity* β, *the absolute value of the determinant itself is not greater than* $\beta^n\sqrt{n^n}$; and the details of the proof are concerned with a still further specialisation made originally by Hadamard himself, namely, *If in each row of a determinant the sum of the squares of the absolute values of the elements be* 1, *the determinant itself is in absolute value not greater than* 1. Tonelli's discussion of the theorem is full and thorough. The ultimate basis of it, as in the case of the first of Muir's proofs, is the theorem regarding the product of a pair of special 2-by-n arrays. A section is devoted (pp. 213–215) to the case where the elements are real: another section to the case where they are, as with Nanson, co-ordinates of points in n-dimensional space: and a third (pp. 216–218) to the case where they are complex.

AMOROSO, L. (1910 /6).

[Sul valore massimo di speciali determinanti. Giornale di Mat., xlviii, pp. 305–315.]

The main part (§ 1) of this paper is occupied with the finding of upper limits for

$$\begin{vmatrix} \int_a^b f_1(x).u_1(x)d(x) & \dots & \int_a^b f_1(x).u_n(x)dx \\ \dots & \dots & \dots \\ \int_a^b f_n(x).u_1(x)dx & \dots & \int_a^b f_n(x).u_n(x)dx \end{vmatrix}^2,$$

where the functions involved, both the f's and the u's, are real and integrable between the limits a and b. The remainder (§ 2) discusses cases where specialisation is made in the functions, and ends by showing that Hadamard's theorem for real elements is one of these.

SZÁSZ, O. (1910, 1911, 1914).

[Az Hadamard-féle determinánstétel egy elemi bebizonyitása. Math. és phys. lapok, xix, pp. 221–227.]

[Ein elementarer Beweis des Hadamardschen Determinantensatzes, Math. u naturw. Berichte aus Ungarn, xxvii, pp. 172–180.]

[Egy determinánstélelröl. Math. és phys. lapok, xxiii. pp. 1–4.]

Szász' mode of treating the theorem is quite different from any of the preceding. The Hermitian determinants concerned being $|a_{rs}|_n$ and $|a'_{rs}|_n$, where a_{rs} and a'_{rs} are conjugate complex, and their product $|p_{rs}|_n$, he seeks of course to prove that

$$|p_{rs}|_n \leq p_{11}p_{22} \dots p_{nn}.$$

To this end he sets about transforming

$$|a_{rs}|_n \text{ and } |a'_{rs}|_n \quad \text{into} \quad |b_{rs}|_n \text{ and } |b'_{rs}|_n$$

in such a way that the product

$$|b_{rs}|_n \cdot |b'_{rs}|_n, \quad \text{or} \quad |q_{rs}|_n \text{ say,}$$

may have its non-diagonal elements all zeros—in other words, so that

$$|q_{rs}|_n = q_{11}q_{22} \dots q_{nn}.$$

His next task is to show that

$$p_{11}=q_{11},\ p_{22}\geqq q_{22},\ p_{33}\geqq q_{33},\ \ldots\ldots,\ p_{nn}\geqq q_{nn}$$

which easily leads him to

$$p_{11}p_{22}\ \ldots\ p_{nn}\geqq q_{11}q_{22}\ \ldots\ q_{nn},$$

i.e. $$\geqq |\,q_{rs}\,|_n$$

i.e. $$\geqq |\,p_{rs}\,|_n,$$

as desired. It must be noted, however, that neither of the two portions of the proof, though both are elementary enough, are such as bring conviction in a line or two ; and still greater fullness might have been advantageous. The transformation of $|a_{rs}|_n$ into $|b_{rs}|_n$ is effected by taking over the elements of the first row unchanged, by taking for the second row the original second row diminished by x_{21} times the new first row, for the third row the original third row diminished by x_{31} times the new first row and x_{32} times the new second row, and so on, the values of the x's being determinable by means of the conditions attaching to the non-diagonal elements of the product $|b_{rs}|_n \cdot |b'_{rs}|_n$. As a matter of fact the actual determination is not carried out, as it suffices in the second part of the proof to use the conditional equations instead.

Attention is next devoted to Fischer's generalisation of 1907, and Szász gives a proof of it in the form : *If* M *be an oblong array of complex elements, then* MM′ *is not greater than the product of any two complementary coaxial minors of* MM′. Also, following up an idea of Nanson's, he shows that *If every coaxial minor of a Hermitian determinant be positive, then the determinant is not greater than the product of any pair of its complementary coaxial minors.*

Boggio, T. (1911 /4).

[Nouvelle demonstration du théorème de M. Hadamard sur les determinants. Bull. des Sci. Math., (2), xxxv, pp. 113–116.]

This clearly worded demonstration, though not identical with Szász', is essentially on the same lines. It might be called a new and improved version.

Kneser, A. (1911).

Die Integralgleichungen und ihre Anwendungen in der mathematischen Physik, viii+243 pp., Braunschweig.]

As might be expected in a text-book with the above title, the author devotes a full section (§ 61, pp. 227–231) to Hadamard's theorem and its cases ; and, as he bases his proof on the theory of orthogonal transforma-

tion, he naturally opens with a page or two on this subject, giving a careful proof of the theorem that *An orthogonal substitution is always formable in which the coefficients of a row are proportional to given quantities that are not all zero.*

HEYWOOD, H. B., and FRECHET, M. (1912).

[L'équation de Fredholm, et ses applications à la physique mathématique (chap. ii, pp. 50–52). vi+165 pp., Paris.]

The proof of Hadamard's theorem here given is on the same lines as Wirtinger's of 1907, differentiation being used. The elements of the determinant are taken to be real.

KUBOTA, T. (1912 $^{1}/_{6}$).

[Hadamard's theorem on the maximum value of a determinant. Tôhoku Math. Journ., ii, pp. 37–38.]

The proof here given concerns the case where the elements are real. In style it is gradational, the n^{th} case being deduced from the $(n-1)^{\text{th}}$ by the use of an orthogonal substitution.

CIPOLLA, M. (1912 $^{27}/_{8}$).

[Sul teorema di Hadamard relativo al modulo massimo di un determinante. Giornale di Mat., l, pp. 355–359.]

Here the writer offers what he justly calls a direct and very simple proof founded on elementary properties of the product of two oblong arrays and on the development of a determinant according to products of the elements of a row and column; and what we actually get is naturally a simplified edition of Hadamard's own proof.

BLASCHKE, W. (1912 $/_{9}$).

[Ein Beweis für den Determinantensatz Hadamards. Archiv d. Math. u. Phys., (3), xx, pp. 277–279.]

The proof in question is different from any of those preceding it, but the difference is really somewhat less than might at first sight appear. To commence with, the author says that by expanding $|a_{11} \ldots a_{nn}|$ in terms of the elements of its first row and their cofactors he obtains

$$\begin{aligned} &|a_{11} \ldots a_{nn}||a'_{11} \ldots a'_{nn}| \\ &= \sum a_{1k}a'_{1k} \cdot \sum A_{1k}A'_{1k} - \sum (a_{1r}A' - a_{1s}A'_{1r})(a'_{1r}A_{1s} - a'_{1s}A_{1r}) \\ &> \sum a_{1k}a'_{1k} \cdot \sum A_{1k}A'_{1k}, \end{aligned}$$

not noting the fact that he is actually using like Muir (1908) the theorem regarding the two equivalents for

$$\left\| \begin{matrix} a_{11} & a_{12} & \dots & a_{1n} \\ A'_{11} & A'_{12} & \dots & A'_{1n} \end{matrix} \right\| \quad \left\| \begin{matrix} a'_{11} & a'_{12} & \dots & a'_{1n} \\ A_{11} & A_{12} & \dots & A_{1n} \end{matrix} \right\|.$$

The after-procedure is made clearer, as in the case of other proofs, by the author pointing out the meaning of each corresponding step of it when $a_{r1}, a_{r2}, \dots, a_{rn}$ are taken to be the co-ordinates of a vector in n-dimensional space.

DIXON, A. C. (1913 $^{9}/_{4}$).

[On the greatest value of a determinant whose constituents are limited. Proceed. Cambridge Philos. Soc., xvii, pp. 242–243.]

What is contained here is a fresh proof of Hadamard's theorem in the form enunciated by Szász, save that the start is now made from an oblong array instead of a square array. In character it is gradational, and might quite fairly have borne Szász' descriptive term "elementary." To establish the theorem for an m-by-n array use is twice made of it for an $(m-1)$-by-n array, namely, once in regard to a primary coaxial minor of the product and once in regard to a primary coaxial minor of the adjugate of the product.

MOLINARI, A. M. (1913 $^{1}/_{7}$).

[Sul teorema di Hadamard. Atti . . . Accad. dei Lincei (Rendiconti), (5), xxii, pp. 11–12.]

The form here established is the so-called Fredholm's. The proof is essentially geometrical, actual orthogonal transformation being utilised.

SZÁSZ, O. (1917 late).

[Ueber eine Verallgemeinerung des Hadamardschen Determinantensatz. Monatshefte f. Math. u. Phys., xxviii, pp. 253–257.]

The main theorem here established, although rightly viewed as the title indicates, is more manifestly a generalisation of Nanson's hitherto unproved theorem of 1902 regarding axisymmetric determinants. In fact what Szász proves is that the said theorem of Nanson holds not only for an axisymmetric determinant but also for a Hermitant whose conjugate elements are conjugate complex.

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A NEW SUNDEW, *DROSERA REGIA* (STEPHENS), FROM THE CAPE PROVINCE.

By Edith L. Stephens.

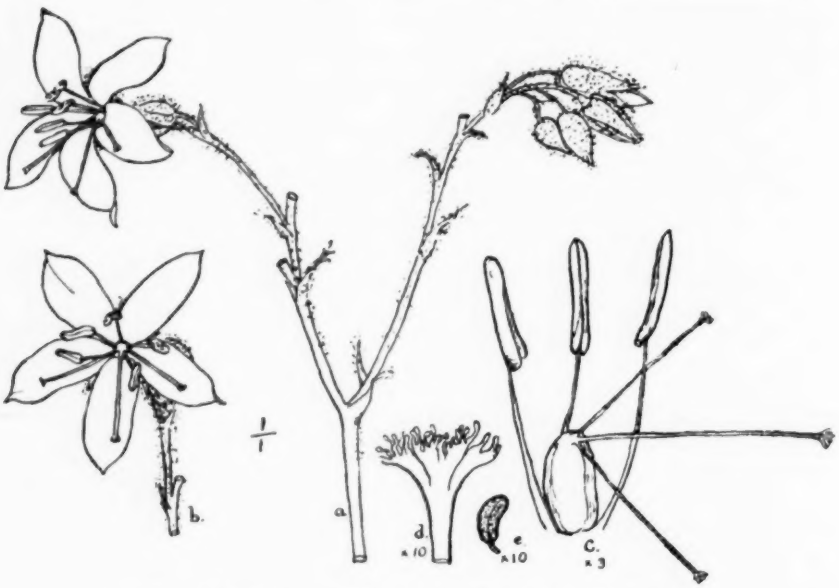
(With Plate XX, and one Text-figure.)

This interesting new species of Drosera was brought to my notice by Mr. J. Rennie, who found several plants growing at Easter 1923 by the stream in the upper end of Baviaans Kloof, which runs up from Bains Kloof on the north side of the Lower Sneeuwkop (near Wellington). Subsequent visits in search of flowering specimens showed that the seed had evidently been washed down from the plateau above, between South Ridge Peak and Observation Point, where it grows socially along the stream, and Dr. Barnard and Mr. Primos and Mr. Stokoe have found it again this year at a locality about four miles off, below Slanghoek Peak near the headwaters of the Witte River. Visiting these localities, the writer has noticed that the plant does not descend into the valleys below, in the marshy areas of which other species of Drosera flourish in abundance, and experiments in cultivation show that it needs a moist and comparatively cool atmosphere, such as is provided by the south-east cloud at these heights (about 3000 ft.). Possibly this may be connected with the very copious secretion of the tentacles, a secretion so viscid as to ensnare even grasshoppers and small beetles. The plant flowers during January and February, the seed is shed by the end of March, and it dies down during the winter months.

Drosera regia, spec. nov. (Sect. Psycophila).

Caulis abbreviatus adscendens vel fere horizontalis, superne pedunculoideus erectus, inferne reliquis persistentibus foliorum dense tectus, tubera elongata gracilia parce emittens. Folia 6–12, exstipulata, omnia basalia, e basi paulo dilatata vaginante caulem amplectente, equitantia, erecta, linearia, apicem versus circinnata vel recurva et saepe leviter spiraliter torta, 25–35 cm. longa (in umbrosis ad 70 cm. longa), 6–20 mm. lata, supra medium gradatim attenuata, setaceo-acuminata, integra, tentaculis crebris coccineis vel atro-rubris supra et glandulis sessilibus viridis vel coccineis utrinque,

praecipue supra, onusta ; nervo medio conspicuo latoque inferne ad 3 mm. lata. Pedunculus foliis plerumque aequalis, interdum longior, inferne teres, superne compressus, nudus, glaber ; inflorescentia cincinnata, ramosa, ad 8 cm. longa, ramis primariis 2·5–5 cm. longis ; bracteae inferiores oblongo-lanceolatae laceratae, ad 1 cm. longae, superiores lineari-lanceolatae vel lineares, setaceo-acuminatae, glanduloso-ciliatae, circa 5 mm. longae ; pedicelli teretes, glandulosi, 1–1·5 cm. longi. Sepala lineari-lanceolata,



D. regia. *a*, Inflorescence (3 flowers removed) ; *b*, flower ; *c*, gynaecium and three stamens ; *d*, stigma ; *e*, seed.

acuminata, extus capillis glanduliferis coccineis dense onusta, 10–12 mm. longa. Petala patentia, dilute rosea ad purpurea, unguiculata, 2–3 cm. longa, lamina obovata, ad 8 mm. lata, apice acuta reflexaque, post anthesim calyptratim supra ovarium conglutinata. Stamina erecta, ultra dimidium laminae attingentia, protandra. Styli 3, stamina parum excedentes, rosei ad purpurascentes, patentes, secundi, 15 mm. longi ; stigma in segmenta brevissima laceratque 2–3 partita. Capsula circa 4 mm. longa ; semina numerosa, ad ·75 mm. longa, atrata, obscure reticulata.

An herbaceous plant with a short ascending or almost horizontal stem terminating in a long erect peduncle, and clothed below by the persistent remains of the leaves of former years. One or two slender elongated root-

tubers are formed annually. The *leaves* are erect and equitant, 6–12 being produced each year, clasping the stem with a slightly sheathing base, linear, circinate or recurved (and often spirally twisted) towards the apex, 25–45 cm. long (in shaded spots up to 70 cm.), 6–20 mm. broad, gradually tapering above the middle to a setaceo-acuminate apex, furnished on both surfaces (but chiefly on the upper) with many minute sessile green to crimson glands, and provided on the upper surface with numerous crimson to deep-red tentacles, which also fringe the edge of the leaves. The midrib forms a conspicuous ridge up to 3 mm. broad on the lower surface. The *inflorescence* is cincinnate; the peduncle is terete but slightly compressed above, ebracteate and glabrous, generally about the same length as the leaves, but sometimes exceeding them; the two primary branches are 2·5 to 5 cm. long, and the pedicels 1–1·5 cm. long, furnished with glandular hairs; the lower bracts oblong-lanceolate and lacerate, up to 1 cm. in length, the upper linear-lanceolate or linear, seta eo-acuminate and covered with glandular hairs, about 5 mm. long. The *sepals* are linear-lanceolate, acuminate, covered on the outside with glanduliferous crimson hairs, and 10–12 mm. long. The *petals* are spreading, pale to deep pink or even purple, clawed, 2–3 cm. long; their lamina is obovate, 8 mm. broad, apex acute and slightly reflexed. After flowering, the withered petals remain as a twisted cap on top of the fruiting ovary. The *stamens* are erect and rather more than half the length of the petals. The flower is protandrous. The *styles* are three, a little longer than the stamens, pink to purple, spreading in a secund manner, 15 mm. long; the stigma is very shortly 2–3 lobed, each lobe being lacerate. The *capsule* is about 4 mm. long, the seeds numerous, up to ·75 mm. in length, brown-black, and covered with fine reticulate marking.

This plant owes its specific name to its striking appearance. The flowering stalk is topped with a cluster of conspicuous pink flowers and surrounded by the erect and glistening linear leaves, a foot or more in length. (The threadlike leaves of the N. American *D. filiformis* are the only ones equalling this in the genus.) The fact that a plant of such distinctive aspect should have remained undiscovered, in a locality comparatively near the long-established highway of Bains Kloof, shows once more what a rich field still remains for the investigator in the flora of the south-west Cape. Apart from this, it is of interest as belonging to a section hitherto unrepresented in South Africa, the ten remaining South African species belonging to the sections Rossilis and Ptycnostigma. The inflorescence is not typical for this section, being several-flowered, whereas the other three species in it are nearly always one-flowered; but other characters are in agreement. One of these species occurs in South America, the other two in Australia and New Zealand.

My thanks are due to Mr. Rennie and Mr. Stokoe, both for supplying material and for guiding me to the localities where they had found it; and to Dr. Barnard for a further supply of material. The photograph of the living plant was taken *in situ* for this paper by Mr. Stokoe, and both photographs were kindly prepared for the press by Mr. E. J. Steer. For the drawings of the inflorescence and flower I am much indebted to Miss M. A. Pocock.

EXPLANATION OF PLATE.

Fig. 1. *Drosera regia.* Flowering plants growing on a grassy slope between rock-ledges, below Slanghoek Peak.

Fig. 2. Herbarium specimen (in bud) showing habit.

Fig. 2.

Fig. 1.

Photo by T. P. Stokoe.

Neill & Co., Ltd.

ON SOME STRONGYLID NEMATODES OF THE AFRICAN ELEPHANT.

By H. O. Monnig, B.A., Ph.D.
Veterinary Research Officer, Onderstepoort, Pretoria.

(With seventeen Text-figures.)

The specimens forming the material of this paper were collected from elephants shot in the Addo Bush, Cape Province. The location of the parasites was given only in one case, viz. *Grammocephalus clathratus* found in the bile-ducts. The material consists of seven different species, of which four are new.

Genus Murshidia, Lane, 1914.

Murshidia brachyscelis n. sp.

A single male specimen was found. It is straight and much smaller than any of the other species of this genus, measuring 8·3 mm. in length with a thickness of 0·3 mm. at its middle. The cuticle is finely striated at intervals of 9μ. The mouth collar is well developed and separated from the rest of the body by a distinct groove. The head has a dorsoventral diameter of 0·16 mm. The external leaf crown arises from the inner surface of the buccal capsule and consists of twenty-four leaflets which are shorter dorsally and ventrally than laterally. The mouth collar bears four prominent submedian and two broad, short lateral papillae. The mouth capsule has the shape of an oval ring flattened from side to side and higher laterally than dorsally and ventrally. Its external diameter, dorsoventrally, is 0·12 mm. The "three sharp, curved, cuticular flanges, one surmounting each of the three muscular oesophageal columns," described by Lane (1921) in his generic diagnosis of *Pteridopharynx*, are present also in this species. There is an oesophageal funnel 0·12 mm. deep, showing the feathered arrangement which is usually found in species of *Pteridopharynx*. The oesophagus is 0·46 mm. long and relatively broad, with a constriction 0·22 mm. from the anterior extremity of the body, where the nerve ring surrounds it. There are two thin, long cervical papillae, directed cephalad and placed 0·85 mm. from the anterior extremity. The excretory pore opens 0·73 mm. from the anterior end.

The bursa is well developed but short ; the rays are typical for the genus. The ventral rays are close together and reach the edge of the bursa. The externo-lateral turns ventrally away from the other laterals and ends in a papilla which projects slightly beyond the margin of the bursa. The medio- and postero-laterals are parallel. The externo-dorsal is smooth, it arises

Murshidia brachyscelis n. sp., anterior end.
FIG. 1.—Lateral view. FIG. 2.—Ventral view.

Murshidia brachyscelis n. sp., male tail.
FIG. 3.—Dorsal view. FIG. 4.—Lateral view.

at the very base of the dorsal stem and runs near to the postero-lateral, not quite reaching the margin of the bursa. The dorsal ray has a broad base which gives off two branches, each again dividing at once into three rays. Of these rays the medial one of each side is the shortest. There are two similar alate spicules which are slightly bent, the tips being bent forwards ; they are 0·75 mm. long. There is a small curved accessory piece, and a telamon is also present.

Genus QUILONIA Lane, 1914.

Quilonia africana Lane, 1921.

This species is represented by three males and twelve females.

Genus Pteridopharynx Lane, 1921.

Pteridopharynx brevicapsulatus n. sp.

The material consists of eight males and twelve females. The worms are practically straight, and the body does not taper much towards the extremities except in the case of the female tail. The male is 13 mm. long and 0·43 mm. thick at the middle of the body, the female is 16·8 mm. long and 0·59 mm. thick. The mouth collar is separated from the rest of the body by a groove and bears four prominent submedian and two broad, short lateral papillae. The cuticle is finely striated at intervals of 11μ; on the head it is smooth. The external leaf crown arises from the lining of the buccal capsule, and consists of forty leaflets which are 0·047 mm. long laterally and shorter dor-

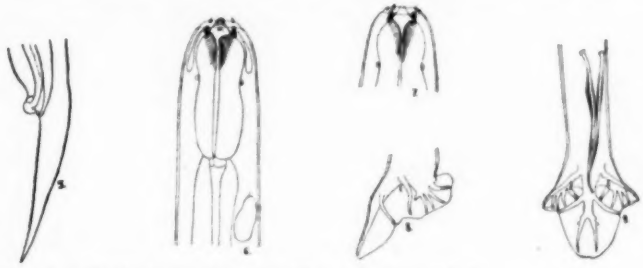


Fig. 5.—*Pteridopharynx brevicapsulatus* n. sp., female tail.
Fig. 6.—*Pteridopharynx brevicapsulatus* n. sp., anterior end, lateral view.
Fig. 7.—*Pteridopharynx brevicapsulatus* n. sp., anterior end, dorsal view.
Fig. 8.—*Pteridopharynx brevicapsulatus* n. sp., male bursa, lateral view.
Fig. 9.—*Pteridopharynx brevicapsulatus* n. sp., hind end of male, dorsal view.

sally and ventrally. The buccal capsule has the usual appearance, it is 0·17 mm. broad dorso-ventrally and 0·022 mm. deep laterally in the female; cuticular flanges are present at its base.

In the male the oesophagus is 0·52 mm. long and relatively broad, with a constriction around which the nerve ring is placed 0·25 mm. from the anterior extremity of the body. The excretory pore opens 0·79 mm. from the anterior end. The bursa is well developed, showing a relatively long dorsal lobe. The ventral rays have a common stem which is about as long as each branch; the latter are close together and do not quite reach the edge of the bursa. The three lateral rays diverge slightly from one another, and the postero-lateral bears a well-developed backward projection at its base. The externo-dorsal ray arises at the base of the dorsal stem and runs outwards with a slight backward curve. At its base there is a small backwardly directed knob, and slightly more distally it bears a prominent caudally directed branch. The dorsal ray gives off a branch on each side before it

bifurcates; these two branches have bifid tips, showing that they are made up of two fused branches each. The terminal dorsal branches bear a number of irregular prominences on the lateral aspect of their bases, and end near to the margin of the dorsal lobe. There are two equal alate spicules, 0·98 mm. long, more or less straight with the tips bent sharply ventralwards. There are a curved accessory piece and a small telamon.

In the female the cervical papillae, which are long, thin, and directed cephalad, are placed 0·98 mm. from the anterior extremity. The nerve collar is placed 0·27 mm. from the anterior end and the excretory pore 0·83 mm. The oesophageal funnel, which shows the usual feathered arrangement, is 0·14 mm. deep. The whole oesophagus is 0·54 mm. long, the anterior portion 0·19 mm. and the posterior 0·35 mm.; the former has a diameter of 0·23 mm. and the latter 0·21 mm. The chyle intestine is more or less straight, and its cells are darkly pigmented. The tail is fairly long, bent ventrad, and acutely pointed; the anus is situated 1 mm. from the tip of the tail and the vulva 1·09 mm. The vagina is directed anteriorly and the two uteri are parallel.

Discussion.—Ware (1924) and Witenberg (1925) come to the conclusion that *Memphisia* Khalil 1922 must be regarded as a synonym of *Pteridopharynx* Lane 1921. From the description of the above species this becomes even more evident. *Pteridopharynx brevicapsulatus* has all the characteristics of the genus in which it is placed, and in addition it has the posterior branch of the externo-dorsal ray as found in *Memphisia memphisia*, but not the cuticular collar. Unless these two genera are made into one it would be very difficult to place this species. *M. memphisia* and *M. aziza* therefore become *Pteridopharynx memphisia* and *P. aziza*. Witenberg uses the name *Pterygopharynx* instead of *Pteridopharynx*; his *Pterygopharynx neveu-lemairei* should be named *Pteridopharynx neveu-lemairei*. *Memphisia rhinocerotis* Neveu-Lemaire 1924 would also become *Pteridopharynx rhinocerotis*.

Genus Amira Lane, 1914.

Amira sameera Khalil, 1922.

Khalil described this species from a single male. Unfortunately my material consists of only five females; but although the measurements do not all correspond to those given by Khalil, there is a close resemblance, and it does not seem justifiable to create a new species on the slight differences of measurements. Gedoelst (1922) records a female of *Amira pileata* from the African elephant. This is probably *A. sameera*, but unfortunately no description nor drawings are given.

The worms are fairly stout and taper only slightly anteriorly, more posteriorly. They are 11·5–12 mm. long and 0·65 mm. thick. The cuti-

cular striations are 8μ apart at the end of the first third of the body and the cuticle is 6μ thick. The mouth collar is distinctly separated from the rest of the body by a groove and is a good deal narrower anteriorly than posteriorly; it is 0·31 mm. broad and 0·07 mm. high. The external leaf crown arises from the cuticular lining of the buccal cavity and consists of forty-two plates 0·08 mm. long. Cervical papillae were not found. The mouth capsule is 0·22 mm. in diameter and 0·078 mm. deep. It is thicker anteriorly than posteriorly. The oesophageal funnel is typical, 0·24 mm. deep and 0·16 mm. wide. The whole oesophagus is 0·75 mm. long, the anterior portion 0·25 mm. by 0·33 mm. wide, and the lower portion 0·5 mm. by 0·27 mm. The chyle intestine is straight, moderately thick, and darkly pigmented, except its very beginning, which is clear. The excretory pore is placed 0·45 mm. from the anterior end and the nerve collar 0·29 mm. The anus is situated 0·62

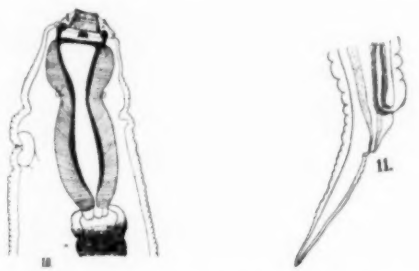


FIG. 10.—*Amira sameera*, anterior end, lateral view.
FIG. 11.—*Amira sameera*, tail of female.

mm. from the tip of the tail, the latter being fairly long, acute, and bent dorsad. The vulva is placed 0·85 mm. from the tip of the tail. The vagina runs straight forward and there are two parallel uteri. The eggs measure 39μ by 35μ and are segmented when laid.

Genus GRAMMOCEPHALUS Raill. and Henry, 1910.

Grammocephalus clathratus Baird, 1868.

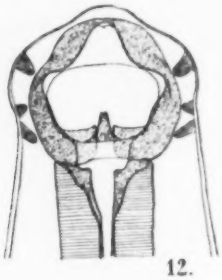
From the bile ducts of the African elephant.

Genus BUNOSTOMUM Raill., 1902.

Bunostomum brevispiculum n. sp.

A single male specimen was found. The worm is 12·1 mm. long and 0·073 mm. broad. The cuticle is finely striated at intervals of 0·003 mm.

The anterior end is flexed dorsad, and the mouth opening is situated on the dorsal side. There are six circumoral papillae of which two are lateral and four submedian. The buccal cavity is lined with highly refractive chitin varying in thickness in different places and thus forming a sinuous line in optical section. The buccal cavity is longer ventrally (0·157 mm.) than dorsally and has a dorsoventral diameter of 0·118 mm. At its base there is a moderately large dorsal tooth 0·043 mm. long with bifid tip, and two slightly smaller subventral teeth. The oesophagus is provided with a small funnel lined with chitin ; the whole oesophagus is club-shaped and 1·02 mm.



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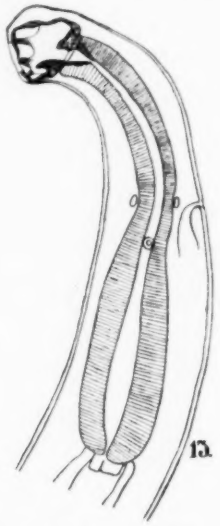

13.

Fig. 12.—*Bunostomum brevispiculum* n. sp., head, dorsal view.
Fig. 13.—*Bunostomum brevispiculum* n. sp., anterior end, lateral view.

long. The nerve ring is placed around the oesophagus 0·52 mm. from the anterior end of the body, and the excretory pore opens slightly behind this level. There are a pair of fairly thick, blunt cervical papillae placed a short distance behind the level of the excretory pore. The bursa is well developed and the dorsal lobe is asymmetrical. The ventral rays have a common stem which is longer than the two branches ; the latter lie close together and do not reach the margin of the bursa. The lateral rays originate from a thick stem which divides about half-way down the length of the lateral lobe. The externo-lateral ray diverges widely in a ventral direction from the other two ; the medio- and postero-laterals are directed somewhat dorsad, run close together, and reach the margin of the bursa. The right externo-

dorsal ray comes off very high from the dorsal stem, it is thin and runs a sinuous course into the right lateral lobe. The left externo-dorsal ray is

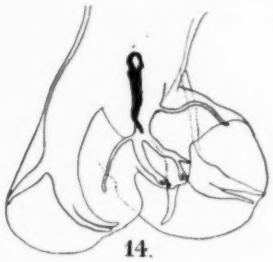

FIG. 14.—*Bunostomum brevispiculum* n. sp., male bursa, dorsal view.
FIG. 15.—*Bunostomum brevispiculum* n. sp., male bursa, lateral view.

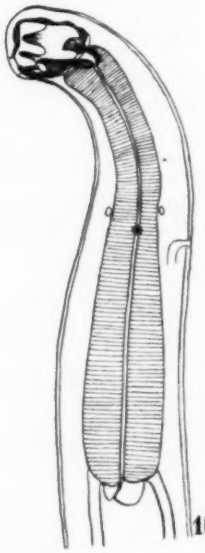

FIG. 16.—*Bunostomum hamatum* n. sp., anterior end, lateral view.
FIG. 17.—*Bunostomum hamatum* n. sp., hind end of male, lateral view.

given off just anteriorly to the bifurcation of the dorsal ray and passes into the left lateral lobe. The two branches of the dorsal ray have tridigitate

tips which differ in the two rays. The specimen shows only one small spicule and no gubernaculum ; probably the other spicule was lost in some or other way. The spicule is alate, 0·224 mm. long, and twisted irregularly ; it is thickest at the proximal end and narrows considerably towards the tip.

Bunostomum hamatum n. sp.

Also only a single male was found. It is smaller than the previous species, being 8·7 mm. long and 0·086 mm. thick. The cuticle is striated at intervals of 0·003 mm. It has the same general appearance of the mouth capsule as the previous species, with a slightly longer dorsal tooth (0·055 mm.) and two subventral teeth. The buccal cavity is 0·161 mm. long along the ventral surface with a dorsoventral diameter of 0·118 mm. The nerve ring is situated 0·50 mm. from the anterior extremity and the excretory pore 0·58 mm. The cervical papillae are placed on a level between these last two points. The oesophagus is 1·08 mm. long.

The male bursa has the same general appearance as in the preceding species, but differs from it in the case of the ventral rays whose common stem is shorter than the two branches. There are two equal alate spicules, 0·67 mm. long, with their distal ends sharply bent dorsalwards and the extreme tips curved back in the form of small hooks. A gubernaculum is absent.

Discussion.—Cobbold in 1882 described *Strongylus foliatus* from the Indian elephant, and Railliet, Henry, and Bauche (1914) placed this species in the genus *Bunostomum*. This has been followed by some discussion as to whether such a step was justified, and the opinion is held by some authors that a new genus will have to be created for this Nematode, which has never been found again since Cobbold's description. The description of the above two species, which clearly belong to the genus *Bunostomum*, would seem to support the idea that Cobbold's species also belongs to that genus. Unfortunately Cobbold's paper was not accessible, but since it has so far been found in every case that the African elephant harbours other species than the Indian elephant, there is very little probability that either of the above two species would be identical with *Bunostomum foliatum*.

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GLYCOLYSIS IN BLOOD.

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The decrease in the quantity of sugar in the blood which takes place after the removal of the latter from the body has formed the subject of considerable study. It has been shown to occur in the absence of micro-organisms and is thought by many workers to be the result of enzyme action. According to Lepine and Barral (1), the enzyme is derived from the leucocytes, and it is stated by Doyon and Morel (2) to occur only in the serum. It has been demonstrated that, during the process of glycolysis *in vitro*, a formation of lactic acid from the sugar occurs; however, the administration of glucose by the mouth in humans has recently been shown by Mendel, Engel, and Goldscheider (3) to cause no change in the lactic acid of the blood *in vivo*. The suggestion has been made that the glycolytic property of the blood is due to a pancreatic enzyme, and the diabetes resulting from extirpation of the pancreas is explained by the supporters of this view by the removal of the enzyme with the gland. Even on the assumption that this theory is correct, it does not explain the disappearance of the large amount of sugar which occurs in the body.

Another possibility is that synthesis of a more complex carbohydrate may take place, and the existence of a specific glycolytic enzyme has been denied by some authors.

Whatever the cause of glycolysis, it is stated to be especially active in the corpuscles, and the factors which have been said to favour it include defibrination of the blood, the addition of anticoagulants, and the presence of abundance of oxygen. It is partially, if not completely, inhibited by laking the blood with water, and a similar effect is produced if the corpuscles are thoroughly washed by centrifuging with isotonic saline.

The rate of glycolysis seems to vary considerably in the blood of different species of animals; for example, it is stated to be almost absent in the blood of the ox, sheep, and pig (Melvin (4)), and it also appears to vary in different individuals of the same species and in the same individuals

at different times. Birchard (5) states that the sugar content of oxalated human blood decreases with moderate regularity, 12 per cent. of the original sugar disappearing in the first three, 22 per cent. during the first six, and 32 per cent. during the first twenty-four hours after taking the blood. If the proteins are precipitated, and the protein-free filtrate kept on ice, or with the addition of xylol at room temperature, the sugar content remains constant for thirty-six hours. It has been found by Aibara (6) that the serum of dog's blood, which has been freed from all formed elements, does not undergo any loss of sugar, and this author also states that sodium fluoride and potassium oxalate prevent glycolysis, but that sodium citrate has no such action. Fuentes and Rubino (7) report that small quantities of calcium chloride increase glycolysis, while if this salt is added in large amounts it exercises an inhibitory action. The effect of mercuric chloride in a concentration of 0·5 grm. per 100 c.c. is also inhibitory, but a smaller percentage (below 0·05 grm. per 100 c.c.) causes an increase in glycolysis.

The effect of temperature has been studied by incubating the blood at 37°–38° C. In bird's blood treated in this way, Ruter (8) has found practically no loss of sugar during a period of three hours. Bierry, Rathery, and Kourilsky (9) find that a temperature of 38° maintained for twenty-four to forty-eight hours causes a diminution, sometimes to zero, in the free sugar. The protein sugar, according to these authors, diminishes more slowly, and there may even be an initial increase. Bierry and Moquet (10) state that the decrease in the free sugar is accompanied by an increase in the inorganic phosphorus of the blood, after a small initial fall. This, they consider, points to the formation of a hexose-phosphorus compound.

It has been suggested that, in diabetic conditions, glycolysis is less active. Thalhimer and Perry (11) quote figures which show, in nine cases of diabetes, percentage decreases in twenty-four hours varying between 9 and 69, with an average of 48·3. In six normals, after administration of glucose, the decrease in the same period varied between 35 and 84 per cent., the average being 55·4. It seems, in the writer's opinion, hardly wise to draw definite conclusions on such a small number of cases. Denis and Giles (12) also state that glycolysis is much less in diabetic than in normal blood. On the other hand, Burger (13) states that only in some diabetics was there diminution in glycolysis, and this author correlates the loss of sugar with the degree of acidosis, supporting this by the statement that the addition of β-oxybutyric acid retards glycolysis and that acetone in small quantities accelerates and in large amounts reduces it.

The theory that glycolysis is reduced in diabetic blood is definitely opposed by Tolstoi (14), Mauriac and Aubertin (15), and Cajori and Crouter (16), none of whom could find any evidence to this effect.

From these brief introductory notes it will be clear that, while it must be agreed that glycolysis undoubtedly does take place, the circumstances which may modify its rate and extent are by no means satisfactorily established. Details are now appended of certain experiments carried out by the author with a view to obtaining some additional information on (*a*) the rate of glycolysis in whole blood under different conditions; (*b*) the loss of sugar, if any, in protein-free filtrates; and (*c*) the ultimate fate of the destroyed sugar.

(*a*) The Rate of Glycolysis in Whole Blood.

This question was studied by means of six experiments:—

(i) Oxalated human blood, taken and preserved under sterile precautions and kept at room temperature.
(ii) Oxalated human blood, kept at room temperature without precautions.
(iii) Oxalated sheep's blood, kept at room temperature without precautions.
(iv) Oxalated human blood, kept in small and accurately measured quantities at room temperature without precautions.
(v) Diabetic blood, kept as in (iv).
(vi) A comparison of the effect of different anticoagulants on human blood, kept at room temperature without precautions.

Experiment (i).—Four separate samples of blood were dealt with. In each case 10 c.c. were taken with sterile precautions and transferred to a sterile oxalated bottle. From this 0·5 c.c. was introduced into a number of sterile ampules, these being immediately sealed in a flame. Maclean's method (17) of estimating the sugar was used, and determinations were made at varying intervals, with the results shown in the following table:—

[Table.

TABLE I.

Time.	Specimen.	Percentage sugar.	Percentage loss.	
Original blood	*a*	0·100		
	b	0·083		
	c	0·087		
	d	0·088		
24 hours	*a*	0·090	10·0	
	b	0·075	9·6	
	c	0·076	12·6	
	d	0·076	14·0	Average 11·6
48 ,,	*a*	0·041	59·0	
	b	0·040	51·8	
	c	0·044	49·4	
	d	0·042	52·3	,, 53·1
72 ,,	*a*	no estimation.		
	b	0·036	56·6	
	c	0·038	56·3	
	d	0·039	55·7	,, 56·2
96 ,,	*a*	0·028	72·0	
	b	0·023	72·3	
	c	0·029	66·7	
	d	0·027	69·3	.. 70·1
Sample *a* was further investigated as follows:				
140 hours	..	0·020	80·0	
144 ,,	..	0·021		
164 ,,	..	0·015		
188 ,,	..	0·010	90·0	
212 ,,	..	0·007		
236 ,,	..	0·005	95·0	

The second series of experiments was carried out on oxalated human blood, obtained by finger-prick or vene-puncture. One or two c.c. of blood was received into a small oxalated tube and sugar determinations made immediately. The blood was then allowed to stand in the laboratory until required for further estimations, which were carried out after periods of 24 and 48 hours. A distinction was made between finger-prick blood and

that obtained from a vein. The results of the estimations are given in the subjoined table.

TABLE II.

	No. of sample.	Original sugar. Per cent.	Loss in	
			24 hours. Per cent.	48 hours. Per cent.
Blood obtained from vein	2	0·091	12·1	51·6
	3	0·090	14·4	52·2
	6	0·102	12·7	55·0
	8	0·107	12·2	50·0
Average . . .	..	..	12·9	52·2
Blood obtained from finger-prick.	1	0·112	17·9	55·4
	4	0·085	16·5	57·7
	5	0·096	16·7	56·3
	7	0·082	15·9	53·7
	9	0·086	17·4	53·5
	10	0·080	16·3	56·3
	11	0·091	16·5	56·0
	12	0·078	17·9	50·4
	13	0·110	13·6	55·5
	14	0·091	16·5	55·0
	15	0·073	15·0	56·2
	16	0·081	16·0	50·1
	17	0·088	15·9	53·4
	18	0·090	16·7	55·6
	19	0·072	16·7	57·0
	20	0·087	16·1	52·9
Average . . .	..	..	16·4	54·7

It will be seen from the table that the venous blood appeared to lose less sugar, both after 24 and after 48 hours, but as among the first twenty estimations there were only four upon venous blood, it was decided to obtain more information on this point by making further determinations on this type of blood. This was done with the following results :—

[TABLE.

	No. of sample.	Original sugar. Per cent.	Loss in	
			24 hours. Per cent.	48 hours. Per cent.
Blood obtained from vein	21	0·089	11·2	50·7
	22	0·092	14·6	42·8
	23	0·086	12·0	53·3
	24	0·085	15·2	55·0
	25	0·086	11·9	53·6
	26	0·093	14·1	56·2
	27	0·090	13·2	55·2
	28	0·094	13·4	53·4
	29	0·086	16·2	50·2
	30	0·090	12·6	51·4
	31	0·076	14·7	51·9
	32	0·088	13·6	53·0
Average . . .	..	..	13·6	52·2
Average of all venous bloods . .	..	..	13·4	52·2

Sixteen samples of each type of blood were thus investigated, and it will be seen that in 24 hours the loss in venous blood was 3 per cent. less than that in finger blood, and in 48 hours 2·5 per cent. less.

The fluctuations in the loss of sugar, which apparently bear no relation to the original sugar content of the blood, gave rise to the possibility of a surface phenomenon being involved, and it was decided to measure off accurately two equal volumes of blood for estimation at the end of 24 and 48 hours, instead of leaving the blood in one vessel for the whole period.

This would tend to neutralise any error which might possibly be introduced through the comparison of figures obtained from unequal volumes of blood. Before giving the figures for the experiment carried out on these lines, those obtained from Experiment (iii), on oxalated sheep's blood, treated in the same way as the human blood in Experiment (ii), are appended (Table III, p. 329).

These figures do not support the statement, mentioned previously, that glycolysis is almost absent in sheep's blood ; in fact, after 24 hours, it appears to be comparable to that in human blood. There is, however, a considerable difference after 48 hours, the loss in sheep's blood being only about half that observed in human blood. In view of the divergence of sample 56 * from the others in this group, it will probably be better to leave it out of calculation ; this brings the averages to 12·8 and 24·3 respectively.

TABLE III.

No. of sample.	Original sugar. Per cent.	Loss in			
		24 hours. Per cent.	48 hours. Per cent.	72 hours. Per cent	96 hours. Per cent.
47	0·080	6·3	22·5	..	52·5
48	0·060	13·3	31·7		
49	0·072	14·0	23·6		
50	0·063	7·9	20·6	36·5	
51	0·058	13·8	27·6	..	65·5
52	0·072	11·1	22·2		
53	0·055	10·9	27·3	49·0	
54	0·073	15·0	24·7		
55	0·084	16·7	..	25·0	55·9
*56	0·062	29·0	37·0		
57	0·074	12·2	21·6		
58	0·068	14·7	23·5		
59	0·063	8·0	20·6		
60	0·081	13·6	23·5		
61	0·070	21·4	25·7		
Average . .		13·9	25·2		

In Experiment (iv), as mentioned above, the blood was divided into three portions, two of which were of equal volume, 0·5 c.c. being placed in each of two ampules of the same size, so that approximately each had the same relative surface exposed to the air. The remainder of the blood was used for an immediate estimation. As will be seen by reference to Table IV (p. 330), which gives the details of this experiment, the limits of fluctuation were smaller, both in the 24-hour period and also in the 48, than in Experiment (ii). In every case the blood was obtained by finger-prick, so that, for comparison, the finger-prick blood in Experiment (ii) must be taken.

These figures show a slightly lessened diminution from those obtained in Experiment (ii), but it seems doubtful whether this can be correlated with the exact measurement of the samples. In order to prove this point, it would be necessary to make a far greater number of estimations, not only upon the lines already mentioned, but also using different volumes of blood. While it would appear interesting, this investigation has, for the present, been sacrificed to others having a more important practical bearing.

In the fifth series of experiments, observations were made upon diabetic

TABLE IV.

No. of sample.	Original sugar. Per cent.	Loss in	
		24 hours. Per cent.	48 hours. Per cent.
33	0·061	14·7	54·0
34	0·116	15·5	52·6
35	0·105	14·3	52·4
36	0·077	15·6	53·3
37	0·096	15·6	53·1
38	0·079	14·0	53·2
39	0·108	14·0	51·0
40	0·092	14·1	53·3
41	0·084	15·5	52·4
42	0·104	15·4	51·0
43	0·082	15·9	51·2
44	0·092	15·2	54·3
45	0·087	14·9	52·9
46	0·095	14·8	53·7
Average	..	14·8	52·7

blood, using the same technique as described under (iv). The results obtained were as follows :—

TABLE V.

No. of sample.	Original sugar. Per cent.	Loss in	
		24 hours. Per cent.	48 hours. Per cent.
62	0·340	14·4	49·3
63	0·334	12·8	49·3
64	0·410	12·9	55·1
65	0·423	14·9	57·1
66	0·243	14·8	54·7
67	0·376	15·3	55·3
68	0·349	14·2	54·7
Average	..	14·2	53·6

The number of cases examined is rather small to draw any definite conclusions, but there is no evidence in the seven above mentioned to show that glycolysis in diabetic blood is less than in normal blood.

There appears to be little in the literature dealing with the comparative effects of different anticoagulants on glycolysis. As has already been mentioned, it is stated that, on the one hand, glycolysis is favoured by the addition of anticoagulants in general and, on the other, that sodium fluoride and potassium oxalate prevent it, but that sodium citrate has no inhibitory action. These latter findings are specifically applied by the observer to dog's blood, and, since it has already been shown that glycolysis does not proceed at a uniform rate in all species of animals, it may be that an explanation may be found in this fact for the apparent contradiction in evidence.

The present author's experiences in this connection are confined to human blood, together with one series of determinations made on blood from a cat which had been anaesthetised with ether and had also suffered some abdominal manipulation. The results of the experiments carried out are given in Table VI.

TABLE VI.

Sample 1. *Cat's Blood.*—The high sugar value is accounted for by the combined effects of ether anaesthesia and stimulation of the splanchnic nerves by abdominal manipulation. Care was taken to avoid excess of anticoagulant.

	Initial sugar content.	Loss in		
		24 hours. Per cent.	48 hours. Per cent.	72 hours. Per cent.
Potassium oxalate .	0·355	4·2	9·9	8·4
Sodium citrate . .	0·355	4·2	43·3	92·3
,, fluoride .	0·355	nil.	5·6	7·0
Potassium oxalate plus a trace of formalin	0·355	4·2	9·9	3·4

[TABLE.]

Human Blood.

No. of sample.	Initial sugar content. Per cent.		Loss in 24 hours. Per cent.	Loss in 48 hours. Per cent.
2	0·056	C.	32·1	51·8
		F.	28·6	34·0
3	0·072	C.	23·7	58·8
		F.	15·6	32·3
4	0·058	C.	30·0	61·3
		F.	17·4	29·6
5	0·079	C.	31·1	56·3
		F.	21·2	30·3
6	0·075	C.	29·2	59·7
		F.	18·7	25·9
7	0·080	C.	31·5	54·5
		F.	19·3	31·4
8	0·074	C.	28·2	49·8
		F.	11·2	27·4
9	0·072	C.	30·2	51·3
		F.	18·4	29·0
Average loss—				
sodium citrate . . .			29·4	55·4
,, fluoride . . .			18·8	30·0

C=sodium citrate. F=Sodium fluoride.

Considering these figures with those obtained with potassium oxalate (given in Table IV), it appears that, for the first 24 hours, the sugar content is preserved best by oxalate. In 48 hours the disappearance is least with sodium fluoride, there being little to choose between citrate and oxalate. It is not concluded, however, in view of the wide fluctuations in the sugar content after these periods, that the nature of the anticoagulant is the only factor influencing the disappearance of sugar from the blood, and it is also difficult to correlate the results given immediately above with those obtained in the case of the cat's blood, unless upon the assumption that, in the latter, a change is brought about in the chemical composition of the sugar which enables it to be, as it were, fixed by the anticoagulant.

(*b*) The Loss of Sugar in Protein-free Filtrates.

The only figures relating to this point, which appear in the literature, are those given by Birchard (5). This author found that, in protein-free

filtrates prepared by Folin and Wu's method (18), only in two cases out of thirteen estimations was there any loss of sugar in the filtrate after a period of 36 hours. These two cases showed a loss after 24 hours of 3·8 and 8·1 per cent. With the object of confirming Birchard's findings and also of comparing, from this point of view, protein-free filtrates prepared by Folin and Wu's and by Maclean's method, the present author carried out a series of ten estimations by each method, with the results shown in Table VII.

TABLE VII.

No. of sample.	Initial sugar content. Per cent.		Loss in 24 hours. Per cent.	Loss in 48 hours. Per cent.
78	0·081	F.	1·4	4·5
		M.	1·6	4·9
79	0·072	F.	1·0	2·7
		M.	1·1	3·0
80	0·077	F.	0·0	2·2
		M.	0·7	2·9
81	0·081	F.	2·6	3·5
		M.	2·4	3·9
82	0·069	F.	2·2	4·7
		M.	2·5	5·0
83	0·094	F.	0·4	1·9
		M.	0·6	2·1
84	0·083	F.	1·3	2·6
		M.	1·3	2·7
85	0·085	F.	0·8	2·5
		M.	1·1	2·6
86	0·072	F.	0·6	3·0
		M.	0·7	2·9
87	0·075	F.	0·4	1·9
		M.	0·9	2·8
Average by Folin and Wu's method			1·1	3·0
,, ,, Maclean's method			1·3	3·3

F = Folin's method. M = Maclean's method.

It will be remembered that Folin and Wu's method of precipitating the blood proteins consists of laking the blood with water and adding sodium tungstate and sulphuric acid. These combine to form tungstic acid, which precipitates the proteins. In Maclean's method, the blood is

heated in the presence of acid sodium sulphate and dialysed iron added. The author's experience with these methods indicates that it is almost impossible to prepare a filtrate which is absolutely free from all trace of protein, and it may be that this trace is responsible for the fluctuating results observed under apparently similar conditions, or, at all events, a contributing cause.

The average of the ten estimations undertaken shows a slightly higher loss in the filtrates prepared by Maclean's method, after both 24 and 48 hours. Only in one case was no loss at all seen after 24 hours ; the results therefore do not agree with those of Birchard, but it must be pointed out that the filtrates prepared by this author were kept on ice for the period during which they were under observation and this possibly accounts for the discrepancies, although the same worker reports that keeping the whole blood on ice did not inhibit glycolysis.

The writer's opinion is that possibly the disappearance of the sugar may be due to an oxidising enzyme, and that varying conditions in the substrate may be set up by the mechanism of the protein precipitation which are reflected in a varying amount of glycolysis. It is also possible that the relation between the volume of the filtrate and the original sugar content of the blood may exert an influence. It is, of course, impossible to formulate a definite theory until an explanation has been found of the exact manner in which the sugar disappears from the blood.

It may be of interest to record here the results of some experiments on hydrolysis of blood filtrates. Cooper and Walker (19) found that, after hydrolysis of blood with hydrochloric acid, the reducing power was increased, but its determination was complicated by the destructive action of the acid on the reducing substance and by the retarding effect on reduction produced by the sodium chloride formed. The second of these difficulties is avoided in the method used by the writer, which was as follows : a protein-free filtrate is prepared by Maclean's method and 20 c.c. of this is then boiled, for ten minutes with 0·5 c.c. of concentrated sulphuric acid. The resulting solution is then almost neutralised to litmus with saturated potassium carbonate and the volume made up to the original 20 c.c. with sodium sulphate. The reducing power of the solution is then determined by carrying out the rest of the technique as described by Maclean.

Very variable results were obtained, except in cases where the original filtrate had completely lost its reducing power. In these it is somewhat remarkable to observe that hydrolysis is without effect. So far, no explanation can be offered either for this fact or for the variable results seen in the other cases. The figures are tabulated below.

TABLE VIII.

No. of sample.	Before hydrolysis.	After hydrolysis.	Actual increase.	Percentage over original.
1	Nil	Nil	Nil	Nil
8	0·074	0·090	0·016	21·6
11	0·091	0·120	0·029	31·9
17	0·054	0·104	0·050	92·6
16	0·068	0·072	0·004	6·0
18	0·090	0·121	0·031	34·4
38	0·037	0·040	0·003	8·1
39	0·025	0·030	0·005	20·0
41	0·084	0·105	0·021	25·0
43	0·020	0·025	0·005	25·0
44	0·092	0·125	0·033	35·9
47	Nil	Nil	Nil	Nil
51	,,	,,	,,	,,
55	,,	,,	,,	,,
58	0·068	0·098	0·030	44·1
59	0·063	0·075	0·012	19·0
60	0·081	0·098	0·017	21·0
61	0·070	0·079	0·009	12·9

Leaving out numbers 16, 17, and 38, which represent extremes, the average percentage increase is 26·4 in those cases which exhibited a rise as the result of hydrolysis.

(*c*) The question of the ultimate fate of the destroyed sugar is under investigation, and will form the subject of another paper.

SUMMARY.

(i) Sterile oxalated blood loses practically all its sugar in ten days at room temperature. The greatest loss appears to take place in the second 24 hours.

(ii) The loss of sugar in venous blood kept at room temperature after 24 hours averaged 3 per cent. less, and after 48 hours, 2·5 per cent. less than that in blood obtained from a finger-prick.

(iii) Sugar disappears from oxalated sheep's blood in amounts averaging 13·9 per cent. in the first 24 hours and 25·2 per cent. in the first 48 hours. After 72 hours, between 25 and 49 per cent., and after 96 hours, between 52·5 and 65·5 per cent. was lost. The statement of other observers that glycolysis is almost absent in sheep's blood is not confirmed. In 24 hours

the amount lost is comparable to that in human blood, but after 48 hours the loss is only about half that seen in human blood.

(iv) In carefully controlled samples of oxalated human blood, so contrived as to offer the same relative surface to the air, smaller fluctuations were observed, but the number examined is too small to warrant any definite conclusions as to the relation, if any, between the surface exposed to the atmosphere and the amount and rate of glycolysis.

(v) From an examination of seven diabetic bloods, no evidence was found that glycolysis in diabetic blood is less than that in normal blood.

(vi) Sodium fluoride appears to preserve the sugar content better than sodium citrate, but for the first 24 hours neither of these anticoagulants is as effective as potassium oxalate. In 48 hours the disappearance seems to be least with fluoride.

(vii) Birchard's findings with regard to the loss of sugar in protein-free filtrates prepared by Folin and Wu's method are not confirmed. It is suggested that small amounts of protein in the filtrate, which it is very difficult to avoid, may exert an influence in determining the degree and rate of glycolysis. Maclean's filtrates appear to lose slightly more sugar than those prepared by the method of Folin and Wu.

(viii) Hydrolysis of filtrates, prepared by Maclean's method, resulted for the most part in an increase in reducing power; the degree of increase was, however, very inconstant. Where the original filtrate was negative as regards its power to reduce Maclean's copper-iodine solution, it was found that hydrolysis failed to alter this, and the hydrolysed filtrate also was inactive.

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ON THE PRESENCE OF α-HYDROXY ACIDS IN BLOOD.

By Arthur Dighton Stammers.

(From the Department of Physiology, University of the Witwatersrand, Johannesburg.)

In an endeavour to account for the ultimate fate of the sugar which disappears from the blood as a result of glycolysis, it was considered desirable to examine certain specimens of blood for oxidation products of glucose, and the following are notes of some experiments carried out.

When glucose is oxidised, *in vitro*, by nitric acid, saccharic acid is formed, and may be recognised by the formation of the potassium hydrogen salt on the addition of potassium acetate.

It occurred to the writer that some information on the point in question might be obtained by the examination of a protein-free filtrate from blood which had been drawn and allowed to stand for some days. This was accordingly prepared by Folin and Wu's method (1) and tested for the presence of saccharic acid. The blood had undergone putrefaction, and it was considered possible that by the action of micro-organisms oxidation to this acid might have taken place. The filtrate from 250 c.c. of blood was evaporated to small bulk on a water-bath, saturated while still hot with potassium carbonate, and slight excess of glacial acetic acid added. It was found on cooling that a crystalline precipitate was formed, which, on microscopic examination, appeared to resemble potassium hydrogen saccharate. This precipitate was filtered off, redissolved in the smallest possible quantity of water, and an attempt made to confirm its identity. Saccharic acid, when treated with phenylhydrazine, forms a diphenylhydrazide, insoluble in alcohol and ether, but soluble in alcoholic soda, and melting at 210° C. The dissolved precipitate was therefore treated with phenylhydrazine hydrochloride and sodium acetate and heated for 40 minutes on a water-bath. On cooling, a yellowish precipitate appeared, which was filtered off by suction and thoroughly washed with distilled water, in which it appeared to be practically insoluble. The resulting product was of a yellowish-white colour and had the solubility properties of the diphenylhydrazide mentioned above, *i.e.* it was insoluble in ether and alcohol, but readily soluble in alcoholic soda.

It was then dried and Bülow's test applied (3 mg. of the dried solid was dissolved in concentrated sulphuric acid, and two drops of 10 per cent. ferric chloride added. The presence of the diphenylhydrazide of saccharic acid is denoted by the formation of a reddish-violet colour); this test was positive. A determination of the melting-point was next made, and this proved to be in the neighbourhood of 185° C., very considerably lower than that stated.

The original product was therefore shaken for some time with ether and alcohol and subsequently well washed with distilled water, when the melting-point rose to 208°.

It was concluded from this evidence that the presence of saccharic acid in the putrefied blood was established.

After separation of the saccharate as described above, a further white crystalline precipitate was obtained, which, after separation from the more soluble residue, was purified and identified as mucic acid. It exhibited the characteristic microscopic appearance of this acid and, on determination of the melting-point, was found to decompose at 210° C., thus confirming the opinion formed after microscopic examination.

Later an attempt was made to repeat the work, but in this case the blood had been preserved with toluol and an entirely negative result was obtained. Blood freshly drawn was also examined, but the quantity used was very much smaller than in the previous cases, only about 5 c.c. being available, so that this may account for the negative result also seen in this case.

The occurrence of α-hydroxy acids in blood and the circumstances under which they may be formed has been the subject of considerable discussion, and even in the case of the most common of these, lactic acid, there is by no means unanimity of opinion.

It has been shown by Baumgarten (2) that the primary products of the oxidation of sugar—gluconic, glycuronic, and saccharic acids—can undergo combustion in the diabetic, and glycuronic acid has been demonstrated to exist in the blood of normal individuals (Neuberg (3), Lepine and Boulud (4)), so that it seems reasonable to suppose that sugar oxidation can ordinarily proceed in the body to the stage of glycuronic acid. From the experiment cited above it seems that under the influence of bacterial action *in vitro* a further stage, to saccharic acid, may be reached. Thus—

CH_2OH	CH_2OH	COH	$COOH$
$(CH \cdot OH)_4$	$(CH \cdot OH)_4$	$(CH \cdot OH)_4$	$(CH \cdot OH)_4$
COH	$COOH$	$COOH$	$COOH$
Glucose.	Gluconic acid.	Glycuronic acid.	Saccharic acid.

If it be true that saccharic acid is not formed in the body under ordinary circumstances, which has yet to be proved, the question arises as to the disposal of the glycuronic acid. In this connection many theories have been put forward, into which it is not necessary to enter at the moment. The purpose of this note is to draw attention to the formation of saccharic and mucic acids in blood by bacterial action *in vitro*, and to the fact that, if the latter be inhibited, this oxidation process apparently does not occur, although it may be mentioned that the reducing power of the blood, when this is kept sterile, disappears with moderate rapidity. No explanation of these phenomena can, at present, be offered. Much more work remains to be done before any definite theory can be proposed, but, since this will involve probably some considerable time, it was thought desirable to place on record the preliminary observations which have been made.

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(4) Lepine and Boulud.—Compt. Rend., cxli, 453, 1905.

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Glucose.	Gluconic acid.	Glycuronic acid.	Saccharic acid.

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SOME OBSERVATIONS ON CERTAIN PATHOLOGICAL CHANGES RESULTING FROM INANITION.

By Arthur Dighton Stammers.

(From the Department of Physiology, University of the Witwatersrand, Johannesburg.)

(With three Text-figures.)

This subject has been extensively reported upon by several authors, notably M'Carrison (1), who, in his well-known monograph, "Studies in Deficiency Disease," relates the results of his observations on pigeons, guinea-pigs, and monkeys. Certain factors such as appetite, sex, segregation, etc., exercise a marked effect on the onset of deficiency disease, quite apart from the actual composition and defects in the food.

In this connection, it was found that male pigeons were more susceptible to the effect of a deficiency set up by the administration of nothing but rice than were females. Again, segregation in pigeons delayed the onset of symptoms to a considerable extent, the segregated birds taking 80 days to develop the disease and the congregated birds 61. This difference, M'Carrison states, was due to the harassed life led by the latter. Further, the demand for vitamins appears to be greater, the greater the physical work.

Cramer (2) states that the effects of cold, warmth, and rest are connected with their influence on the endocrine regulators of metabolism, the adrenal glands especially.

Harden and Zilva (3) have produced symptoms of oedema in monkeys fed on a diet deficient in vitamin A and low in fat. The symptoms of deficiency disease in pigeons and in monkeys are largely the same, namely, loss of appetite (this is particularly the case following deprivation of vitamin B), diarrhoea, anaemia, rapid loss of weight, low temperature, and slow respiration. A tendency to oedema is also reported to occur in some cases.

These symptoms may also be observed in rats, and, in addition, priapism is common. In the latter stages of neuritis following deficiency of B, and

shortly prior to death, complete paralysis of the lower limbs may, and usually does, result.

As regards the pathological changes in the internal organs, probably the most typical is the gastro-intestinal derangement caused by lesions of the neuro-muscular mechanism. Ballooning of the intestine due to the accumulation of gas is an extremely common condition found on post-mortem examination of animals which have died from deficiency of B, and the author has also observed this symptom where no vitamin deficiency existed. It occurred as an epidemic during a series of experiments with synthetic diets, and, at first, bacterial infection was suspected, but bacteriological examination proved that there was no specific organism involved, and the occurrence remains unexplained.

Another common pathological change recorded by several observers is hypertrophy of the adrenals following defective nutrition. M'Carrison regards adrenal derangement as one of the most important effects of food deficiency on the animal organism, and it is with this condition that the present paper chiefly deals.

The enlargement of the adrenals in such cases is usually associated with an increase in the adrenaline content of the gland. M'Carrison's observations were confined to pigeons, guinea-pigs, and monkeys, and, in all his experiments, he demonstrated that the glands hypertrophied, either as the result of acute inanition consequent on deprivation of all food, or of the more chronic inanition resulting from deprivation of vitamins. The enlargement tended to be less marked when a ration, balanced as regards the proximate principles, was supplied, and more so if the food were disproportionately rich in energy-bearing constituents.

In addition, hypertrophy was accompanied by an increase in the normal adrenaline content of the gland and by an almost complete disappearance of lipoid material from the cortex. In guinea-pigs, however, the hypertrophy was associated with a reduction in the adrenaline content of the gland, the enlargement being due to degenerative and haemorrhagic changes.

The hypertrophy of the adrenals noted in such cases is stated by Funk and Douglas (4) to be a true one, in that a proportional increase of adrenaline occurs in the gland, and M'Carrison found that malnutritional oedema, accompanied by enlargement of the adrenals, was also attended by a considerable increase in adrenaline, particularly in pigeons.

Further, he observed that 70 per cent. of cases of avian polyneuritis among adult pigeons with enlargement of the adrenals also had oedema, and 90 per cent. of young birds, with hypertrophied adrenals, had this condition.

As regards the adrenaline content of the glands, he found that the oedematous birds gave rather less than the normal amount per gram of gland.

The present author has recently investigated certain cases of oedema among cattle slaughtered at the Johannesburg Municipal Abattoir, and part of the routine of this investigation has been a histological examination of the adrenals and an estimation of the adrenaline content of the glands. The appearance of these cattle was such as is usually associated with those coming from a drought-stricken area, and it is most probable that their condition was due to defective nutrition of one kind or another.

Investigations have also been carried out on rats fed upon defective synthetic diets.

The results of these inquiries are now set out, so far as they apply to the subject under discussion. The full report of the research into the cattle disease has appeared in another paper (Stammers (4*a*)).

Four albino rats were placed under observation on 12th May 1924 and fed upon a diet consisting of casein, starch, sugar, salt mixture, and olive oil (Stammers (5)). They were all confined in one cage for purposes of convenience and identified by means of ear-clipping. Since olive oil was used, it was supposed that the diet was deficient in A, B, and C, neither antineuritic nor antiscorbutic being administered. As events turned out, it is somewhat doubtful whether A was entirely absent, since no symptoms of ophthalmia developed in any of the animals. That there was a considerable and definite deficiency in the diet there is no doubt, as all four animals eventually succumbed, but it appears probable that an amount of A was present sufficient to prevent the onset of ophthalmic symptoms.

Be this as it may, the animals undoubtedly suffered from inanition, but it must be borne in mind that the balance of proximate principles in the diet was physiologically correct, and the defect was constituted by the absence of certain specific vitamins. In this respect the experiment does not compare with those of M'Carrison, since the majority of the latter were carried out with one particular type of foodstuff, *e.g.*, autoclaved rice, and a carefully balanced basal ration was, for the most part, not used.

That there was a deficiency of B is proved by the fact that all the animals prior to death exhibited the usual paralysis of the hind legs and priapism, and post-mortem examination revealed, in each case, the typical distension of the intestine associated with death from a deficiency of this vitamin.

The method of examination adopted was that, after death, any naked-eye changes were noted in the internal organs and the adrenals were excised, weighed, and transferred to 10 per cent. formalin. After fixation for 48 hours or more, sections were cut by the freezing method and stained in Sudan III (6) for five minutes, afterwards being counterstained in Delafield's haematoxylin and mounted in glycerin.

During the progress of the experiment, the animals were weighed twice

a week, in the morning before feeding, and the food intake was also determined. A graph is appended (fig. 1) showing the weights recorded and the food consumption during the experiment. It should be mentioned that the animals were adults and had previously been used in another experiment (upon the vitamin content and nutritive value of maize meal, reported elsewhere (Stammers (6*a*))). They were thus not in the best possible condition at the commencement of the experiment, but, nevertheless, would be expected to show more resistance than young animals to a deprivation of vitamins. One in particular did so, surviving for 97 days. The first succumbed very rapidly, the second at the thirtieth day, and the third at the fifty-first day. The loss of weight varied between 0·7 grm. per day in the animals surviving longest and 2·5 grm. per day in the case of the one which died first.

The pathological changes observed have already been touched on. Dealing further with them, it may be mentioned that *Rat* 1, which died eight days after the beginning of the experiment, exhibited few pathological changes apart from the intestinal symptoms. The other organs were normal to naked-eye examination, with the exception of the spleen, which appeared slightly congested. No hypertrophy of the adrenals was observed, the weight of the glands being 0·0282 grm., which is equivalent to 0·269 grm. per kg. of body weight immediately prior to death. Normal rat adrenals weighed 0·269 grm. per kg. body weight. Histological examination revealed that the zones of the cortex were ill-defined. A large amount of lipoid material was present in the cortex, this being particularly profuse in a well-marked layer roughly corresponding to the glomerular zone. Elsewhere, the lipoid globules were scattered fairly evenly throughout the cortex. The general appearance of the rest of the gland was normal.

Rat 2 died 30 days after the commencement of the experiment. The intestinal symptoms were similar to those observed in the previous case. In addition, the lungs were distinctly haemorrhagic, otherwise the viscera appeared normal. There was no hypertrophy of the adrenals, the weight of which was 0·0304 grm., which corresponds to 0·276 grm. per kg. body weight. The histological appearance was similar to that in Case 1, except that the amount of sudanophil material in the cortex was somewhat diminished. The same well-defined layer, corresponding to the zona glomerulosa, was observed, and there appeared to be some necrosis of the cells of the zona fasciculata, these being swollen and granular and the zone broken up in places. The medulla was normal.

Rat 3 died 51 days after the commencement of the experiment, after exhibiting typical symptoms. At the autopsy, the ballooning of the intestines was particularly marked, an area 8 cm. in length being distended to a diameter of 2 cm. The other organs were apparently normal. There

was no hypertrophy of the adrenals, the weight of which was 0·0274 grm., equivalent to 0·266 grm. per kg. body weight prior to death.

Histological examination of the adrenals showed that there was considerably more lipoid material in the cortex than in Case 2, although not so much as in Case 1. As previously, the sharply defined band in the cortex, corresponding to the glomerular zone, was well seen. In this specimen there appeared to be some apparent incipient necrosis of the cells of the cortex, particularly in the glomerular and fasciculate zones, the latter especially. Both cortex and medulla appeared somewhat congested, and some increase in the cellular elements was observed. Large spaces, irregular in size and shape, causing some compression of the persisting cells and presenting a somewhat hyaline or glassy appearance, were present in the cortex, and in the medulla there appeared to be a considerable quantity of unstained fat, due possibly to a degeneration of the medullary cells.

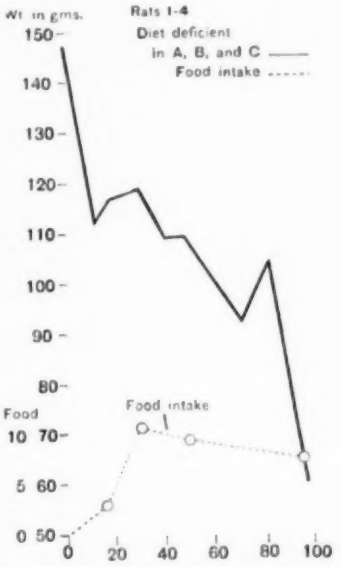

FIG. 1.

Rat 4 survived for 97 days with a total loss of weight of 88 grm. Typical symptoms of paralysis, priapism, etc., were observed prior to death, and at the post-mortem examination the intestines were found to be inflated, although not to the same extent as in No. 3. The other organs appeared normal, with the exception of the testes, which were atrophied. When the adrenals were being excised, a small oval-shaped body, 5 mm. in length, 4 mm. wide, and about 1 mm. thick, was observed to be lying slightly medial to the left adrenal and at about the same level. This was removed for histological examination. Its weight was 0·013 grm.

There was again no hypertrophy of the adrenals, which weighed 0·0168 grm., or 0·191 grm. per kg. body weight. The histological examination of the glands revealed that the whole cortex was loaded with lipoid granules, particularly in the subcapsular region and in the fasciculate zone, there being much more sudanophil material in this case than in any of the others examined. The gland presented a normal appearance, and nothing pathological was observed.

The oval-shaped body referred to above appeared on histological examination to be of the nature of lymphoid tissue. It was not normal, however, as it contained many hyaline areas, which stained fairly readily with Sudan III, although not to the same extent as fat.

Commencing on 1st July 1924, two male adult rats were tested with a diet adequate in its protein, fat, and carbohydrate content, but deficient in phosphates. The diet was made up in the usual way with caseinogen, starch, sugar, cod liver oil, and salt mixture, with the exception that the latter had the following composition :—

Sodium chloride	47·25 parts.
Magnesium sulphate	71·68 ,,
Calcium lactate	337·00 ,,
Ferric citrate	31·52 ,,
Sodium fluoride	0·55 ,,
Manganese sulphate	2·00 ,,
Potassium iodide	10·00 ,,

2·5 grm. of dried yeast were also added to each 10 grm. of food.

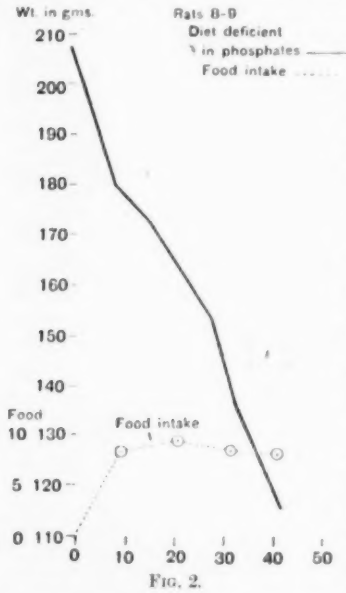

FIG. 2.

Thus the only source of phosphorus available to the animals was the caseinogen. A loss of weight occurred regularly throughout the experimental period, each animal losing nearly 90 grm. in 41 days (fig. 2). The details are as follows :—

Rat 8 died 41 days after the beginning of the experiment. There was no evidence of any definite symptoms, prior to death, except considerable emaciation, the weight having dropped from 212 grm. to 124 grm. during the experimental period. The average food intake was 8·25 grm. per day.

The organs appeared normal. The yellow bone marrow, however, had become gelatinous. The adrenals weighed 0·0272 grm. or 0·22 grm. per kg. body weight. Histologically, a large amount of lipoid was seen in all three zones. There was, however, a lipoid-free band in the zona glomerulosa. Slight congestion was observed.

Rat 9 also died on the forty-first day of the experiment, without ex-

hibiting any characteristic symptoms, except general weakness and emaciation. The weight in this case dropped from 199 grm. to 110 grm. This animal consumed 8·25 grm. per day.

The viscera showed no pathological changes, except the bone marrow, which was gelatinous as in the previous case. The adrenals weighed 0·0262 grm. or 0·238 grm. per kg.

Histological examination revealed a large amount of lipoid, although not so much as in the previous case. This was distributed in much the same way, except that the lipoid-free band was more extensive than in the foregoing. There was slight congestion and some appearance of granulation in the cells of the cortex generally.

In addition to the two series just mentioned, four other rats, two males and two females, commencing on 17th July 1924, were fed upon a basal diet, in which the caseinogen was replaced by a sample of blood meal, prepared at the Johannesburg Abattoir and sold for cattle-feeding purposes.

The analysis of this meal was as follows :—

Protein	71·2 per cent.
Ether extract	0·6 ,,
Moisture	20·3 ,,
Ash	3·4 ,,

The basal diet was made up in the following proportions :—

Blood meal	31·7 per cent.	=22·6 protein.
Starch	48·8 ,,	
Cane sugar	14·7 ,,	
Salt mixture	4·8 ,,	

The food was prepared by incorporating 15 parts of olive oil with 85 parts of the basal diet and making up to a pasty consistency with water.

The usual basal diet used has the following composition :—

Caseinogen	26·0 per cent.
Starch	54·0 ,,
Sugar	15·0 ,,
Salt mixture	5·0 ,,

It will thus be seen that there was a slight deviation from the usual proportions of proximate principles, in the direction of a diminished amount of protein and an increase in carbohydrate. Three of the four rats used succumbed to this diet very quickly, two in 12 days, and the third a week later. The fourth survived for only 27 days. No symptoms beyond severe and rapid emaciation were observed to develop, and the cause of the mortality is unexplained. No vitamin deficiency would have brought

about fatal results in so short a time. A very small amount of food (4–5 grm. per animal per day) was eaten, and lack of appetite was probably responsible for this and for the consequent emaciation. The daily loss of weight varied between 4·1 and 6·3 grm. per animal (fig. 3).

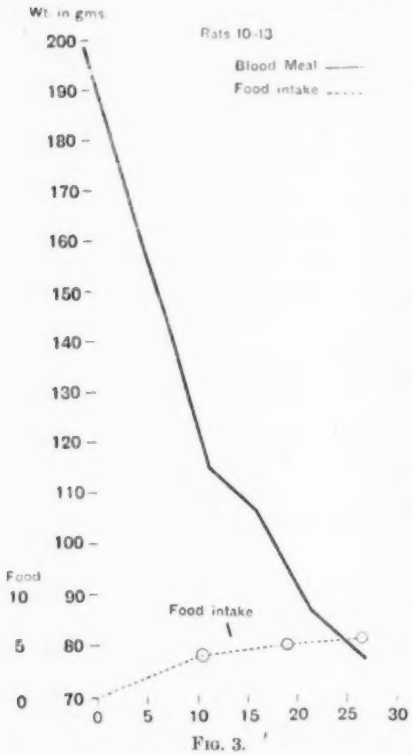

FIG. 3.

The details of these cases are as follows :—

Rat 10 died 12 days after the beginning of the experiment, having dropped in weight from 170 grm. to 110 grm. Post-mortem examination showed evidence of some amount of haemorrhage in the abdominal cavity, probably derived from rupture of intestinal vessels. The other organs appeared normal. The adrenals weighed 0·0212 grm., equivalent to 0·193 grm. per kg.

Histologically, there was little sudanophil material, what there was appearing in the well-defined band in the zona glomerulosa as described previously. There was also a small amount elsewhere, scattered throughout the cortex. The zones were moderately well defined and the cellular elements normal.

Rat 11 also died 12 days after the beginning of the experiment, having lost 76 grm. during this period. Nothing abnormal appeared at the post-mortem examination. The adrenals weighed 0·0456 grm., or 0·304 grm. per kg.

On histological examination, a very large amount of sudanophil material was seen in the cortex, the usual well-marked band in the glomerular zone being prominent. The zones were well defined and the rest of the gland appeared normal.

Rat 12 died 19 days from the commencement, having lost 91 grm. At the autopsy, it was observed that the testes appeared to be atrophied (the age of the animal was 312 days only) and that there was some amount of

haemorrhage in the abdominal cavity. The other organs were normal in appearance. The weight of the adrenals was 0·0233 grm., or 0·245 grm. per kg.

Histological examination revealed that there was a fair amount of lipoid in the cortex, distributed in much the same way as seen previously and that the gland was normal in appearance.

Rat 13 survived for 27 days, during which period the loss of weight was 111 grm. There was nothing abnormal to be seen on post-mortem examination. The adrenals weighed 0·0272 grm., or 0·275 grm. per kg.

When examined histologically, the subcapsular zone of lipoid was well seen. The fasciculate and reticular zones also showed sudanophil material, but not so profusely as the other specimens examined. The cortex appeared very congested. Large blood lagoons were common, pushing aside the columns of cortical cells. There was nothing pathological in the medulla.

Lack of appetite in animals deprived of vitamin B is a notable symptom, according to many workers, and in this connection it is interesting to notice the food consumption of the animals referred to above which is now given in tabular form.

Food.	Reference numbers of animals.	Period of survival, days.	Food intake, per animal per day. Grm.
Deficient in A, B, and C	Case 1	8	2·75
	,, 2	30	10·50
	,, 3	51	9·50
	,, 4	97	7·40
Deficient in phosphates .	Cases 8 and 9	41	8·25
Blood meal . .	Cases 10 and 11	12	4·0
	Case 12	19	5·3
	,, 13	27	5·5

The author's experience hitherto, in experiments of this kind, has been that amounts varying between 10 and 12 grm. per day are usually consumed, at all events in the earlier stages of the experiment, and the above figures indicate a definitely low intake, with the exception, perhaps, of Case 2. The deficiency of the diets in B, in the first and third series, would be expected to be reflected in a lowered food consumption, but this would not apply to the second series in which, by reason of the cod-liver oil and yeast, the vitamin content was adequate.

Details will now be given of observations on the cattle adrenals already referred to. Estimations of the adrenaline content of normal glands from eight oxen yielded the following results :—

Reference number.	Weight of gland.	Live weight of animal.	Ratio $\frac{\text{weight of gland.}}{\text{live weight.}}$	Grm. adrenaline per grm. gland.
	Grm.	Kg.	Grm. per kg.	
21	22	515·5	0·043	0·0038
24	26	543·6	0·048	0·0028
22	22	513·25	0·043	0·0036
25	28	487·0	0·058	0·0030
23	28	607·0	0·046	0·0027
26	22	502·8	0·044	0·0017
27	24	557·2	0·044	0·0024
28	19	453·0	0·042	0·0034
Average	..	..	0·046	0·0029

The method of adrenaline estimation was that devised by Folin, Cannon, and Denis (7). These authors found in the ox an adrenaline content of 0·0039 grm. per grm. of gland, but in no case in the present author's estimations was an amount as high as this found.

The glands from two cases of oedema in cattle were subjected to histological examination and adrenaline estimation with the following results :—

No. 6.—Ox, slaughtered at the Johannesburg Abattoir, 6/6/24. Slight oedema. Live weight, 421·3 kg. Weight of adrenals, 28 grm., or 0·066 grm. per kg. body weight. This indicates some hypertrophy. The adrenaline content was 0·0013 grm. per grm. gland, showing a distinct diminution in adrenaline, in spite of a slight hypertrophy. The histological appearance showed the zones well marked. Some pigment-containing cells were to be seen in the cortex. No sudanophil material was observed. This specimen showed an area in the medulla, probably fibrous in nature and consisting mainly of an apparently structureless matrix, although in places the cell elements were obvious. Certain parts of this area presented a hyaline appearance, and in two places islets of gland tissue were engulfed.

No. 7.—Calf, slaughtered at the Johannesburg Abattoir, 4/7/24. Slight oedema. Live weight, 27·2 kg. Weight of adrenals, 4 grm., or 0·147 grm. per kg. body weight. The adrenaline content was 0·0007 grm. per grm. gland. This case also shows a hypertrophy of the glands and a diminution of adrenaline. The normal calf's adrenal contains a considerably higher percentage of adrenaline than that of the adult ox. Histological examination showed the zones ill-defined and the cortex divided into septa by trabeculae derived from the capsule. There was very little, if any, sudanophil material, but a large amount of pigment, scattered through the cortex, especially in the zona fasciculata.

It may also be appropriate to record here certain histological observations made upon some of the glands from the normal oxen.

No. 21 showed the fat in the capsule well stained, but very little, if any, sudanophil material in the cortex, the zones of which were well defined and normal in appearance. Cells containing pigment granules were numerous, especially in the zona glomerulosa, and were aggregated into nodules in the other zones, which appeared somewhat congested, especially the reticularis.

No. 22 also showed the fat in the capsule well stained, and the cortical zones were well defined and normal in appearance. There was a complete absence of sudanophil material in the cortex and practically no pigment. Some aggregations of lymphocytes were observed in the medulla, especially in the regions surrounding nerves and in the connective tissue between the nerve fibres.

It is somewhat difficult to account for the histological pictures in these cases, but it seems clear, from all the glands examined, that the normal ox adrenal differs considerably in its content of lipoid material from that of the rat, not only in distribution, but also in amount. In no case has the typical appearance of subcapsular lipoid in the rat been observed in an ox adrenal. It is, perhaps, too much to say that the sudanophil material is uniformly deficient in the ox, but it seems to be the case that the condition of oedema affecting numbers 6 and 7 had no marked effect on the histological appearance of the adrenals in these cases. It is considered that the abnormal area in the medulla of number 6 was a condition quite apart from any nutritional disorder.

As regards the pigmented appearance observed in Cases 6, 7, and 21, it may be mentioned that Watrin (8) states that, in adult guinea-pigs, cells containing yellow pigment are a marked feature of the zona reticularis, the appearance not being observed in young guinea-pigs. He suggests that this pigment may be formed at the expense of the lipoid material, but the conditions under which this may happen, and the causes leading thereto, are not postulated.

It is clear from the investigations carried out that in Cases 6 and 7 there was a slight hypertrophy of the glands, which may have been due to malnutrition. Increase in adrenaline content, however, was not manifested.

It may here be mentioned that Kreger (9) has observed that, in cases of inanition in human beings, the adrenal bodies lose little or no weight, while such organs as the spleen, liver, pancreas, heart, testis, thyroid, and kidney exhibit a considerable diminution. This statement implies that malnutritional hypertrophy of the adrenals in human beings is not within the experience of this author, and it by no means follows that, because the condition has been observed in monkeys, pigeons, and guinea-pigs, that therefore, under similar conditions, it must ensue in humans, cattle, and rats.

Enright (10), in observations on Turkish prisoners during the war, found that, owing to the so-called "war-oedema," the adrenals, far from being enlarged, were atrophied.

The author's experiences with rats, as evidenced in this paper, point to the fact that malnutritional hypertrophy of the adrenals, under certain circumstances, *e.g.* proper balance of the diet but deficiency in vitamins, does not occur, and in this connection it may be stated that Rubner (11) considers that the production of malnutrition oedema depends upon an insufficient amount of protein in the diet. This opinion is confirmed by Kohman (12), who states that fats, or vitamins A or B, did not prevent the occurrence of oedema in rats on a low protein diet.

Apropos of this, the present author's experiments with maize meal, reported elsewhere (Stammers (6*a*)), may be mentioned. In this case, six rats successfully withstood a diet consisting of maize meal alone for a period of eighteen weeks. The meal was, of course, ill-balanced in proximate principles, but probably a sufficient amount of protein was consumed, the carbohydrate thus being in excess. At all events, no evidence of oedema was presented.

Maver (13) also found no indication that lack of vitamins was concerned with the production of oedema.

As regards the distribution of lipoid material, Cramer (14) found, in cases of deficiency of vitamin A, an extensive depletion and, in cases of deficiency of B, an irregular distribution. When both were withheld, an almost complete disappearance was reported.

This finding is not confirmed in the four cases of deficiency in both vitamins, which have been discussed above; in fact, the animal which survived the longest had the most lipoid in the adrenals.

Summary.

Certain facts emerge from the comparative obscurity of the data presented. These are as follows:—

1. Malnutrition in rats, when caused by a deficiency in vitamins alone, the proper proportions of the proximate principles of the diet being maintained, causes no hypertrophy of the adrenals and little or no diminution in the lipoid content of the glands.

Where the avitaminosis was prolonged, there appeared to be a certain amount of cellular degeneration, although the case which was most resistant to the deficiency exhibited no unusual features.

2. The adrenals of the normal oxen examined by histological methods were found to be practically free from sudanophil material in the cortex, although that in the capsule stained well. The pigment observed in the

two cases from oedematous oxen may have been formed, as Watrin has suggested, from lipoid material, which was almost completely absent from the glands. This theory is, however, entirely speculative, since two of the glands examined were from supposedly normal cattle, one of which contained a large amount of pigment and the other very little. Again, one contained a small quantity of lipoid and the other none. In these two normal cases, therefore, it is not possible to argue the manufacture of pigment from lipoid, and the same probably applies to those from the oedematous oxen.

3. Oedema, probably malnutritional in origin, though not necessarily associated with avitaminosis, was associated with some hypertrophy of the adrenals, but, far from a proportionate increase in adrenaline being observed, an actual diminution from the normal occurred.

4. The average ratio $\frac{\text{weight of glands}}{\text{live weight}}$ in the normal oxen examined was 0·046 grm. per kg. live weight, and the average amount of adrenaline found was 0·003 grm. per grm. gland. In the two cases of oedema, the figures were 0·066 and 0·147 grm. per kg. and 0·0013 and 0·0007 grm. per grm. gland respectively.

For convenience of reference, the details of the cases described are given in tabular form (p. 354).

Conclusions.

The data presented are somewhat inadequate for any definite conclusions to be drawn at present, and this paper must be regarded as a preliminary communication. The work is being extended, but, in the meantime, a tentative explanation is offered, namely, that (*a*) disturbance in the proximate principles of the diet is responsible for the oedema, with attendant hypertrophy of the adrenals and increase in adrenaline, and for the disappearance of lipoid material observed by other workers, rather than deficiency in vitamins alone ; and (*b*) the observations made on guinea-pigs, pigeons, and monkeys do not necessarily apply to rats and oxen. The differences in the histological pictures between normal rat and normal ox adrenal when stained with Sudan III and haematoxylin is striking.

It is well known that there are considerable differences in the lipoid content of the adrenals of different animals. Nevertheless, the almost complete absence of sudanophil material in the normal glands examined is somewhat remarkable. This is not likely to have been due to the staining method adopted since the fat in the capsule was well shown thereby.

I wish to express my indebtedness to Professor R. W. M. Mettam, Head of the Department of Veterinary Anatomy, University of the Witwatersrand,

No.	Animal.	Diet.	Weight.		Loss.	Period of survival.	Food intake per day.	Adrenals.				Histological notes.	Microscopic pathological changes.
			Initial.	Final.				Lipoid content.	Pigment.	Wt.	Ratio to body wt.		
			Grm.	Grm.	Grm.	Days.	Grm.			Grm.	Grm.		
1	Rat	Def. in A, B, and C.	125	105	20	8	7·5	+ + +	0	0·0282	0·269	Cortical zones ill-defined.	Intestine inflated, spleen slightly congested.
2	,,	,,	165	110	55	30	9·0	+	0	0·0304	0·276	Some necrosis of cells in fasciculata, zone broken up.	Intestine inflated.
3	,,	,,	147	103	44	51	8·7	+ +	0	0·0274	0·266	Some necrosis of cells in glomerulosa and fasciculata, slight congestion of cortex and medulla. Hyaline spaces in cortex, unstained fat in medulla.	Intestinal inflation very marked.
4	,,	,,	155	88	67	97	7·4	+ + + +	0	0·0168	0·191	..	Testes atrophied.
8	,,	Def. in phosphates.	212	124	88	41	8·25	+ + +	0	0·0272	0·220	Cortex slightly congested.	Bone marrow gelatinous.
9	,,	,,	199	110	89	41	8·25	+ + +	0	0·0262	0·238	Slight congestion and granulation of cortical cells.	Bone marrow gelatinous.
10	,,	Blood meal	170	110	60	12	4·0	+	0	0·0212	0·193	..	Haemorrhage in abdominal cav.
11	,,	,,	226	150	76	12	4·0	+ + +	0	0·0456	0·304	..	..
12	,,	,,	186	95	91	19	5·3	+ +	0	0·0233	0·245	..	Haemorrhage in abdominal cav., testes atrophied.
13	,,	,,	210	99	111	27	5·5	+ +	0	0·0272	0·275	Cortex very congested.	..

		Condition.	Adrenaline content.	Lipoid content.				
			Grm. per grm. gland.			Grm.		
21.	Ox	Normal	0·0038	Traces	+ +	22	0·043	Some congestion of cortical zones.
22.	,,	,,	0·0036	0	0	22	0·043	Aggregations of lymphocytes in medulla.
6.	,,	Slight oedema	0·0013	0	+	28	0·066	Abnormal area in medulla.
7.	Calf	,,	0·0007	Traces	+ +	4	0·147	Gland divided into septa.

and to Dr. A. Mavrogordato, of the South African Institute for Medical Research for kind advice and helpful criticism, also to Mr. A. C. Kirkpatrick, Assistant Director of the Johannesburg Municipal Abattoir, for kindly placing at my disposal facilities for obtaining some of the material referred to in this paper.

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TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XIII.

MINUTES OF PROCEEDINGS.

Anniversary Meeting.

The Anniversary Meeting of the Society was held on Wednesday, March 19, 1924, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. Ogg, was in the Chair.

The Report of the Hon. General Secretary was submitted and adopted.

The Report of the Hon. Treasurer was submitted and adopted.

The following were elected members of Council for the year 1924 :—

Mr. K. H. Barnard.	Mr. C. W. Mally.
Dr. J. W. Bews.	Dr. I. B. Pole Evans.
Dr. W. A. Caldecott.	Dr. J. S. v. d. Lingen.
Dr. J. P. Dalton.	Dr. A. Young.

Dr. A. Ogg was elected President.

Dr. L. Crawford, Hon. Treasurer.

Dr. W. A. Jolly, Hon. General Secretary.

The Hon. General Secretary announced with regret the death of Dr. L. Péringuey, who was one of the Fellows recommended for the Council. It was intimated that the Council would recommend another Fellow in his place.

The President addressed the Society as follows :—

At the Anniversary Meeting of the year, our minds naturally revert to those of this Fellowship whom the past year has taken from us, Sidney Samuel Hough and Louis Péringuey.

Mr. S. S. Hough, M.A., F.R.S., H.M. Astronomer, Royal Observatory, Cape Town, was born at Stoke Newington, London, on June 11, 1870, and died on July 8 1923, at his brother's residence, Gerrard's Cross. During a brilliant mathematical career at Cambridge he showed how the elastic yielding of the earth caused a variation of latitude. He also revised Laplace's "Theory of the Tides" and obtained a more complete solution than had previously been obtained. Sir George Darwin described this work as the most important contribution to this theory since the time of Laplace.

In October, 1898, he arrived in Cape Town to take up the appointment as Chief Assistant to Sir David Gill, whom he succeeded in 1907. As Director of the Observatory he continued the work of Sir David Gill and has made what is probably the most valuable contribution of recent years to the determination of absolute positions of stars and connected problems. His contributions to the Astrographic Catalogue made the Cape section a very valuable contribution to this work, which was nearly completed when he died.

In 1899 he was elected a Fellow of the Astronomical Society, in 1902 a Fellow of the Royal Society, and in 1905 he was awarded the Hopkins Prize by the Cambridge Philosophical Society for the most important memoir of a mathematical, physical character by a graduate of the University during three preceding years.

He was elected a member of the Council of the South African Philosophical Society in 1906 and President in 1907. The S.A. Philosophical Society became by Royal Charter in 1908 the Royal Society of South Africa, and Mr. Hough was elected its first President. He remained President of the Royal Society for four years in succession. The Society was fortunate in having Mr. Hough as President during its early history. He continued to the end to take the keenest interest in the Society, being a member of the Council during the years 1913, 1914, 1917, 1918, 1921, and 1922.

Louis Péringuey, D.Sc., F.E.S., F.Z.S., Director of the South African Museum, died on February 20, 1924. In 1882, Dr. Péringuey, as an honorary worker, arranged the beetle collection of the S.A. Museum. In 1884 he was appointed assistant on the staff of the Museum; in 1896 Assistant Director, and in 1906 Director. Dr. Péringuey's earliest writings were on beetles, the most important being the Catalogue of Coleoptera of South Africa, which, although it does not deal with all the families, may be said to have formed the basis of our knowledge of South African beetles. He published works on Mutillid wasps, Ant lions, and Grasshoppers, and had an unrivalled knowledge of the whole Insect fauna of South Africa.

He was an enthusiastic student of the native races, and stone implements and other relics of prehistoric races. In 1911 he published a comprehensive

treatise on the discoveries in this field up to that date, entitled the "Stone Ages of South Africa."

His Presidential Address to this Society, and his numerous demonstrations and notes in the Proceedings, testify to his wide knowledge and interest in this branch of research.

At the time of his death Dr. PÉRINGUEY had probably a longer active connection with the S.A. Philosophical Society and the Royal Society of South Africa than anyone in South Africa.

He was elected a member of the S.A. Philosophical Society in 1885 and a member of the Council of the Society from 1886–1888, President in 1889 and 1890, a member of the Council from 1891–1896, Secretary from 1896–1898; again President 1899–1900, member of Council 1901–1903, Secretary 1903–1907. During these twenty-two years he was President for four years, Secretary for six years, and a member of Council for twenty-one years.

He was elected first General Secretary of the Royal Society of South Africa in 1908, and continued Secretary for four years. In 1912 he succeeded Mr. HOUGH as President and continued President for six years. In ten successive years he was four years Secretary and six years President. As a member of the Council of 1918, 1920, and 1921, he took a keen and active part in the work of the Society. From 1886 to 1921 he holds an unbroken record, except for 1919, of having acted either as President, Secretary, or member of the Council. In October, 1923, he was proposed as member of Council for 1924, the members of which have been elected to-day.

Dr. PÉRINGUEY was also Secretary of the Regional Bureau of South Africa for the International Catalogue of Scientific Literature.

REPORT OF THE HON. GENERAL SECRETARY FOR 1923.

Eight Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the following papers were read :—

1. "On the Passage of Cathode Rays through Matter," by BASIL F. SCHÖNLAND.

2. "Holtzhuisbaaken Spring, Cradock," by THOMAS STEWART.

3. "Two new species of Nematodes from the Zebra," by GERTRUD THEILER (communicated by Sir ARNOLD THEILER).

4. "Note on Zeipel's Condensation-theorem and related Results," by Sir THOMAS MUIR.

5. "Note on the Heterosomata (Flat Fishes) of South Africa," by C. VON BONDE.

6. "Some Notes on the Drought of 1922-23 on Table Mountain," by THOMAS STEWART.

7. "The Sulphide and Hydrosulphide of Ammonium," by J. SMEATH THOMAS.

8. "Notes on some South African Xylarias," by PAUL A. VAN DER BIJL.

9. "The Crystalline Structure of the Alkaline Sulphates," by A. OGG.

10. "Note on the Successive Differentiation of a Product of Linear Functions," by Sir THOMAS MUIR.

11. "The Differential Bactericidal Effect of the Visible Spectrum," by J. STEPH. V. D. LINGEN.

12. "On the Attraction-Coefficient for Substances of Low Critical Temperature," by JOHN P. DALTON.

13. "X-rays as a Means of detecting Imperfections in Fruit," by C. W. MALLY.

14. "On a Proposed Modification of the Cathode Ray Oscillograph," by E. NEWBERY.

15. "Note on the Polysulphides of Ammonium with some Considerations regarding the Constitution of the Polysulphides of the Alkali Metals," by JOHN SMEATH THOMAS and RICHARD WILLIAM RIDING.

16. "The Active Principle of *Homeria pallida* (Yellow Tulp)," by M. RINDL.

17. "On a form of the Benzene Ring as shown by the Crystal Structure of Naphthalene and Anthracene," by A. OGG.

18. "On a Protozoal Parasite of the Snoek—*Chloromyxum thyrsites* sp. n.," by J. D. F. GILCHRIST.

19. "Note on Cathode Ray Absorption," by B. F. J. SCHÖNLAND.

20. "On Matrices connected with Sylvester's Dialytic Eliminant," by JOSEPH KÜRSCHAK, Budapest (communicated by Sir THOMAS MUIR, F.R.S.).

21. "On an Example of Adaptation in a South African Isopod Crustacean," by K. H. BARNARD.

22. "The Volcanic Rocks South of Zuurberg," by S. H. HAUGHTON and A. W. ROGERS.

23. "Studies in the Morphology of *Selaginella pumila*. Part III: 'The Embryo,'" by A. V. DUTHIE.

24. "On the Genesis of Diamond," by J. R. SUTTON.

25. "On the Action of some Fluorescent Antiseptics in the Dark (Preliminary Note)," by J. S. V. D. LINGEN.

Vol. XI., Parts 1 and 2, of the Society's Transactions have been issued during the year.

Mr. CHARLES MACDONALD STEWART, B.Sc., was elected a Fellow of the Society in 1923.

The number of Honorary Fellows is as before: Fellows 56; Members 161.

The deaths, since the 1923 Anniversary Meeting, of Mr. S. S. Hough, Fellow; Mr. T. P. Kent, Mr. M. Leviseur, Mr. J. M. Orpen, Members; are recorded with regret.

Dr. A. Jasper Anderson, Fellow, is resigning from the end of the year.

Wm. A. Jolly,
Hon. General Secretary.

Ordinary Meeting.

An Ordinary Meeting of the Society was held.

The President was in the Chair.

Business :—

The Minutes of the last Meeting were confirmed.

Professor R. S. Adamson, M.A., B.Sc., proposed by Professor R. H. Compton, seconded by the Hon. General Secretary, was elected to membership.

The following were nominated for membership :—

Professor William Campbell, B.Sc., M.B., Ch.B. (Edin.), and Dr. D. Morrison, B.A. (Cape), M.B., Ch.B. (Edin.).

Communications :—

"Fast Cathode Rays," by B. F. J. Schönland.

Apparatus was described for the production in quantity of cathode rays of velocity up to ·53 of the velocity of light, corresponding to a fall of potential of about 90,000 volts.

With these fast rays the author's experiments on Cathode Ray absorption have been extended until they reach the β-ray region. Several points have been further investigated, the previous work confirmed with improved apparatus, and more data obtained which support the Bohr theory of absorption.

An explanation has been found for the change in the variation of apparent absorption with velocity from element to element.

Experiments on the scattering of these fast rays were described which appear to reach the important single-scattering region.

"The Mineral Germanite and the Extraction of Germanium and Gallium therefrom," by J. Smeath Thomas and William Pugh.

An examination has been made of this mineral which occurs at Tsumeb, S.W. Africa. The previous account given by Pufahl (Metall und Erz 1922, 19, 324) was incomplete inasmuch as the important constituent gallium was entirely overlooked. A spectroscopic examination made by Dr. Lunt of the Royal Observatory revealed the presence of 26 elements, of which the follow-

ing were estimated by the authors:—Cu-44·01; S-30·96; Fe-5·08; As-6·83; *Ge*-5·10; Zn-2·74; Pb-2·26; *Ga*-0·57; $WO_3$0·06; Mo-trace; Au-trace; SiO_2-1·84; $BaSO_4$-0·02. This analysis is in good general agreement with the results obtained quite independently by the chemist at the mine, Herr F. W. Kriesel, the differences being explained by the fact that whilst he worked with carefully selected specimens the authors took a fair sample from 10 kilos of the mineral.

The separation of germanium and arsenic was effected by volatilisation of the chloride in a stream of chlorine, two distillations being necessary. The germanium was then precipitated as sulphide in strongly acid solution, converted to oxide by treatment with conc-nitric acid and weighed as such. Gallium was estimated in a 50-gram sample. After removing germanium and arsenic and the metals precipitated by hydrogen sulphide in acid solution, the liquid was made alkaline with ammonia and then boiled with zinc. The precipitate was dissolved, made alkaline with sodium hydroxide, and zinc removed as the sulphide. Gallium was then precipitated as ferrocyanide in strongly acid solution, converted to oxide by the method of Browning and Porter (Amer. J. Sci. 1917, 44, 221) and weighed in this form.

The mineral is massive crystalline and has a curious reddish-grey tinge. It appears to be intimately intergrown with a green arsenical fahl ore. Hardness 4, sp. gr. 4·595, streaks dark grey. Nodules of iron pyrites were also observed. The action of heat and of acids on the mineral was described.

Processes for the extraction of germanium and gallium were described. In the case of the former element it is essentially the same as the analytical process except that arsenic is first removed by roasting at low temperatures. When heated too strongly germanium was lost. A new process was worked out for the extraction of gallium. This process depends on the great extent to which gallium salts are hydrolysed in solution. For details the original paper should be consulted. This will appear in the forthcoming number of the Journal of the Chemical Society of London.

The reduction of the oxide in hydrogen yields the metal, but this method of preparation is not satisfactory. Reduction with potassium cyanide gives good results, provided the cyanide is pure. A yield of 77 per cent. was obtained, the remainder of the metal being converted into potassium germanite. Using a carefully prepared and dried mixture of potassium cyanide and carbon a yield of 95 per cent. resulted. Moisture and free alkali are especially to be avoided.

"Freshwater and Subaerial Algae of Natal," by F. E. Fritsch and Florence Rich (communicated by Miss Edith Stephens).

An extensive collection by Professor Bews is dealt with in this account, the first to be published on the subject. 228 species are recorded, 145 of which are new records for South Africa; 14 new species and 15 new varieties

are recorded. The most conspicuous rôle is played by the *Cyanophyceae*, which are the dominant forms in many of the samples and are the first plants to invade the bare rock-faces of the mountain cliffs. The chief item of interest from a systematic standpoint is the discovery of an interesting new genus of *Ulotrichales* (named *Pearsoniella* after the late Professor Pearson). This is characterised essentially by its chloroplasts, which assume a form new among the algae, viz. that of a complete ring or girdle encircling the periphery of the cell.

Wm. A. Jolly,
Hon. General Secretary.

TREASURER'S ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1923.

REVENUE.

	£ s. d.	£ s. d.
To Subscriptions for 1923 :—		
Subscriptions collected for 1921	5 0 0	
,, ,, ,, 1922	36 0 0	
,, ,, ,, 1923	273 8 0	
,, ,, ,, 1924	3 11 0	
,, ,, in 1922 for 1923	6 14 0	
Outstanding Subscriptions at December 31, 1923	61 0 0	
	385 13 0	
Less : Outstanding Subscriptions at December 31, 1922, £64 ; and Subscriptions collected in 1923 for 1924, £3, 11s.	67 11 0	
		318 2 0
,, Entrance Fees		13 0 0
,, Government Grant, 1923–4		300 0 0
,, Interest received :—		
On Fixed Deposit, £500, at Standard Bank for 1 year at 4½ per cent.	22 10 0	
On £400 Union of South Africa 5 per cent. Stock to July 31	13 6 10	
On £408 New Union of South Africa 5 per cent. Stock to September 17	2 11 5	
On money in Savings Bank Department of Standard Bank	4 16 2	
		43 4 5
,, Sale of Publications in 1923	37 1 3	
Plus : Amount due for Sale in 1923 ..	0 15 0	
	37 16 3	
Less : Purchase price of copies of Transactions, £19, 6s. ; and amount received in 1923 for sale in 1922, £4, 10s. 2d. ..	23 16 2	
		14 0 1
		£688 6 6

EXPENDITURE.

	£ s. d.	£ s. d.	£ s. d.
By Publications :—			
Cash Paid for Printing, etc., to Neill & Co.	484 3 0		
Cash Paid for Storing to Adlard & Son and West Newman	2 2 6		
		486 5 6	
Less : Contributions towards Publications	33 8 0		
Receipts for extra reprints of Papers	3 5 5		
Amount due for extra reprints of Papers	7 8 5		
Amount due in 1922 for Publications	246 14 11		
		290 16 9	195 8 9
,, International Catalogue of Scientific Papers :— Compilation, £25, purchase of Vol. L, 14th issue, 11s. 1d.			25 11 1
,, Clerical Assistance and Work in Library ..			65 0 0
,, Local Printing and Stationery			52 1 0
,, Postages and Petties			18 12 6
,, Bank Charges for Commissions, Ledger Fee, Fixed Deposit Stamps, etc. ..	3 10 8		
Less : Commissions paid by Members ..	2 4 4		
		1 6 4	
,, Hire of Rooms and Caretaker, 1923			6 6 0
,, Insurance in 1923 :—			
Library, etc., in University Library ..	0 10 6		
Stock held by Adlard & Son and West Newman	0 11 0		
		1 1 6	
,, Dr. Koettlitz Memorial, Subscription, etc.			2 0 8
,, Profit in year 1923			320 18 8
			£688 6 6

Owing to the printers' delay in completing Vol. XI., Parts 3 and 4, which will not be issued till 1924, the accounts for this work cannot be debited to the revenue of 1923, consequently the profit shown for 1923 appears unusually large. It will in due course be disbursed in payment of these accounts.

ASSETS AND LIABILITIES AS AT DECEMBER 31, 1923.

Assets.*

	£	s.	d.
Money at Standard Bank on Fixed Deposit for one year at 4 per cent.	500	0	0
Money in Savings Bank Department of Standard Bank	355	11	8
Balance at Standard Bank as per Pass Book	64	14	0
Union of South Africa £408 5 per cent. Stock 1929/39, reckoned at purchase price	400	0	0
Arrears of Subscriptions, as in Statement for 1922, £64; less £43 paid in 1923 and £8 struck off as irrecoverable	13	0	0
Arrears of Subscriptions for 1923, £51; less £3 struck off as irrecoverable	48	0	0
Amount due for Sale of Publications	0	15	0
Amount due for extra reprints of Papers	7	8	5
	£1389	9	1

Liabilities.

	£	s.	d.	£	s.	d.
Subscriptions received for 1924; in 1922, £2, in 1923, £3, 11s.				5	11	0
Binding Periodicals in Library				16	15	0
Earmarked for Expense of Publishing, as a part of the Transactions, a Reproduction of a Bushman Painting (Council Minutes, May 12, 1915), a sum not exceeding				350	0	0
Balance from 1912 Conversazione carried forward towards the expenses of future Conversazione in Cape Town				7	4	0
Excess of Assets over Liabilities :—						
Amount at December 31, 1922	£689	0	5			
Add Profit in year 1923	320	18	8			
				1009	19	1
				£1389	9	1

* Exclusive of value of Library and Publications of the Society held in Stock.

Entrance Fees and Life Subscriptions Fund.

	£	s.	d.		£	s.	d.
Amount of Fund at January 1, 1923	297	0	0	Amount of Fund at December 31, 1923	310	0	0
Entrance Fees received in 1923	13	0	0				
	£310	0	0		£310	0	0

We hereby certify that we have examined the above accounts of Revenue and Expenditure, and of Assets and Liabilities, with the books, vouchers, and other documents relating thereto, and that in our opinion these accounts set forth a correct statement of the affairs of the Society.

ALEXANDER BROWN,
ANDREW YOUNG.

February 25, 1924.

An Ordinary Meeting of the Society was held on Wednesday, April 16, 1924, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. Ogg, was in the Chair.

Business :—

The Minutes of the previous Meeting were confirmed.

The recommendation by Council was announced of Dr. C. F. Juritz as a member of Council for 1924, in place of the late Dr. L. Péringuey.

Dr. L. B. Goldschmidt, proposed by Dr. A. Reith Fraser, seconded by the Hon. General Secretary, was nominated for membership.

The following were elected Members :—Professor William Campbell, B.Sc., M.B., Ch.B. (Edin.), and Dr. D. Morrison, B.A. (Cape), M.B., Ch.B. (Edin.).

Communications :—

" The Long Bones of the South African Bushman," by Vincent Vermooten (communicated by Professor M. R. Drennan).

In this paper Mr. Vermooten described some of the morphological features, and submitted tables of measurements and indices, of the long bones of a number of South African Bushmen. The material consisted of 38 skeletons, kindly lent for the work by the late Dr. Péringuey of the South African Museum, and of 5 skeletons from the Anatomy Department of the University of Cape Town.

Mr. Vermooten worked out averages, and the extremes of length, of the various bones for Shrubsall's three groups of Bushmen, namely, the Strandloopers, Inland Bushmen, and Hottentots of his series. He also compared the relative length of the limbs in these groups, and the relative length of each segment of the limbs, with corresponding lengths in other races. For this purpose he made use of the Intermembral, Radio-humeral, Tibio-femoral, and Humero-femoral indices.

His researches show that the whole arm of the Bushman is relatively shorter, and therefore less simian, than the arm of the Negro or European, and it is a degree shorter still in the Bushwoman. The radius on the other hand is relatively longer than that of the European, and therefore more simian, but it is not so long as that of the Negro. The tibia is relatively long, and the humerus is relatively short.

" Note on the Heterosomata of Portuguese East Africa," by C. von Bonde.

This paper is based on a collection of Heterosomata (Flat-fish) from Portuguese East Africa, made by Dr. J. D. F. Gilchrist and the late Mr. H. A. T. Hunter.

The collection comprises 20 species belonging to 16 different genera.

One species, *Pardachirus marmoratus* (Lacépède), is of particular interest, having been described before only from the Red Sea and Madagascar. It has now been obtained from Delagoa Bay.

Two new species, *Samaris delagoensis* and *Cynoglossus hunteri*, are here described for the first time.

In their distribution the Heterosomata of Portuguese East Africa are closely related to those of Natal waters, and some new species recently described from Natal have now been found in this region.

Wm. A. Jolly,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 21, 1924, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. Ogg, was in the Chair.

Business :—

The Minutes of the previous Meeting were confirmed.

Dr. C. F. Juritz, M.A., D.Sc., F.I.C., was elected a member of Council for 1924 in place of the late Dr. L. Péringuey.

Dr. L. B. Goldschmidt was elected a Member of the Society.

The Hon. General Secretary announced that the following are candidates for Fellowship in 1924 :—Charles Kimberlin Brain, M.A. (Ohio), M.Sc., D.Sc. (Birmingham) ; John William Cormack Gunn, M.A., M.B., Ch.B. (Edin.) ; Basil Ferdinand Jamieson Schönland, B.A. (Cape), M.A., Ph.D. (Cantab.), O.B.E. ; John Smeath Thomas, D.Sc. (Liverpool), F.I.C., and Paul Andries van der Byl, M.A., D.Sc. (Cape).

Demonstrations :—

" Photographs of an Oar-fish," by Mr. K. H. Barnard.

Photographs of an Oar-fish (*Regalecus glesne*) which was cast ashore at Knysna in April were shown. Some notes on the peculiarities of this rare and supposedly deep-sea fish were given, and attention was drawn to some points on which accurate observations are still needed ; such as the exact shape of the dorsal crest, and whether it is single or divided into two portions, and the food on which this fish lives. A list of the South African records, dating from 1834, was given.

" South African Spiders," by Mr. R. F. Lawrence.

Several genera of South African Thomisidae were exhibited, illustrating imitations of the calyx, leaves and leaf-axils of flowers and the stems of reeds and grasses. *Thomisus albus* commonly seen with its orange-coloured variety on the white and yellow chincherinchee (*Ornithogalum*) in the Cape

Province, *Misumena* described as living on the Oleander, and *Felsina* on *Mundtia spinosa* or Schilpad-bessie on the Cape Flats. *Stiphropus* and *Camaricus* were shown as examples of West and East African Thomisids.

Runciniopsis is much flattened and lies pressed against the stems of grasses, while the straw-coloured form *Monoeses* has the abdomen elongated into a long cylindrical caudiform process and escapes observation by remaining motionless amongst grass or thin reeds.

Communications :—

" The Smaller South African Shells that harbour Cercariae," by F. G. Cawston.

The author describes a number of small snails found in pools in South Africa which act as intermediate hosts of trematode worms.

" Contributions to our Knowledge of the Freshwater Algae of Africa. V : On a deposit of Diatomaceous Earth from Ermelo, Transvaal," by F. E. Fritsch and Florence Rich (communicated by Miss E. L. Stephens).

This deposit occurs as a pan, about half a mile long and 440 yards wide, on the farm Bank-Plaats, and is still being formed at the present day. During the wet season water percolates through the deposit, and living diatoms are found on its surface ; in the dry season these mostly die off, and their siliceous valves form the deposit. Seventeen species of diatoms occur in it ; one of these is new, and several new varieties are also described and figured.

Wm. A. Jolly,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 18, 1924, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. Ogg, was in the Chair.

Business :—

The Minutes of last Meeting were confirmed.

The following were nominated for membership :—Mr. R. F. Lawrence, M.A., and Dr. A. J. Hesse, Ph.D. Proposed by Mr. K. H. Barnard, seconded by the Hon. General Secretary.

Communications :—

" Preliminary Note on Secondary Growth in Some Iridaceae," by R. S. Adamson.

Three closely allied genera, *Nivenia*, *Witsenia* and *Klattia*, possess woody stems with continued secondary growth.

The secondary growth has the same general features as that described for the arborescent Liliaceae, but these plants differ in two features :— (1) The secondary bundles, or the inner ones, are very close together, often in contact. The radial arrangement of cells is obscured to a large extent. The bundles arise from a number of cambium cells. (2) In old stems the secondary tissues are arranged in zones (annual rings) a feature not previously described for monocotyledons.

" Note on Systems of Determinants with Sets of Deleted Elements," by Sir THOMAS MUIR.

"Colour and Chemical Constitution. Part XIX : Organic Fluorescence," by JAMES MOIR.

" On a Skull and Partial Skeleton of *Mesosuchus browni* Watson," by S. H. HAUGHTON.

This paper contains the description of the only known complete skull of *Mesosuchus browni* from the *Cynognathus* beds of Aliwal North, as well as of the front half of the skeleton. The chief general features of the skull are :—Nostrils confluent, not separated by a bony internasal septum ; no antorbital vacuity, orbits large, looking mainly outwards ; upper temporal opening oval in shape ; lower opening squarish ; lower temporal arcade not complete, both the jugal and squamosal ending in free pointed extremities, and the quadratojugal not passing forward from the quadrate ; supratemporal bone present ; teeth acrodont ; beak bent down in Rhynchosaurian manner and carrying two teeth ; pterygoids and vomers carrying rows of teeth ; ectopterygoid large.

The scapula is large, the coracoid single ; clavicles and an interclavicle are present. The humerus is broad proximally with a large deltopectoral crest.

The relationships of the form with *Youngina*, the Sphenodontia, the Rhynchosauria, the Lizards, *Howesia*, and the Thallatosauria, are discussed, and it is concluded that *Mesosuchus* may be placed in a new family, which is called the Mesosuchidae, and placed in a new sub-order of Diapsid reptiles, the *Mesosuchia*.

" A South African Life Table based on the European Male Population Census," by C. W. KOPS (communicated by Prof. J. P. DALTON).

The life table is based on the census returns of 1918 and 1921, and the deaths during the years 1919–1921.

The function graduated is q_x. The graduation was performed by fitting three curves to the data—a quadratic, together with an exponential function for ages 0 to 15, a first-degree function, together with an exponential for ages 24 to 108, and these curves are joined by a cubic function having first-order contact with each of the other curves.

A Makeham graduation was also applied from the age of 20 to the

end of the table. Both graduations are then compared with standard tables from other countries. Graphical comparisons are also made in the case of each graduation.

WM. A. JOLLY,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, July 16, 1924, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. OGG, was in the Chair.

Business :—

The Minutes of last Meeting were confirmed.

It was announced that a Conversazione was held by the Society in the Hiddingh Hall, University of Cape Town, on July 11, at which the members of the South African Association for the Advancement of Science were present as guests.

The following were elected Members of the Society :—Mr. R. F. LAWRENCE, M.A., and Dr. A. J. HESSE, Ph.D.

The following were nominated for membership :—Dr. L. P. BOSMAN, B.A., B.Sc., Ph.D., and Dr. L. MIRVISH, M.A., M.B., Ch.B., proposed by the President, seconded by the Hon. General Secretary; and Prof. G. A. WATERMEYER, proposed by Prof. G. H. STANLEY, seconded by Prof. L. CRAWFORD.

Communications :—

"The Spermatogenesis of *Locustana pardalina* (Walker), (the Brown Trek Locust)," by D. J. MALAN and D. E. MALAN.

The chromosome numbers in over 40 genera of locusts have by now been worked out, and in practically all cases it has been found that 2n=23 (male) and 24 (female). The few exceptions which showed smaller chromosome numbers could all be accounted for by secondary linkage of non-homologous chromosomes, and thus in every single instance could the numbers 23 and 24 be adduced. In five genera belonging to the family Tettigidae the chromosome numbers were found to be 2n=13 (male) and 14 (female). Probably a further study of the chromosomes in this family will bear out its relation, on a chromosome basis, to the locusts. Although chromosome counts have been made of numerous animals, especially insects, during the last fifteen or twenty years, very little work has been done in the case of certain groups, and when these backward groups have once been investigated one may probably be able to look forward confidently to

some interesting relations between classification in the animal kingdom and chromosome numbers.

"A New *Trichostrongylus* from South African Sheep," by H. O. Monnig.

A description is given of *Trichostrongylus rugatus* n. sp. which occurs in the first 8 to 12 feet of the small intestine in South African sheep.

"The Digestive Canal of Isopod Crustaceans," by K. H. Barnard.

The stomach (fore-gut) of a large number of isopods of various families have been examined, and their structure compared with that of *Ligia*, which may be taken as a basic type. One important structure, which apparently has been overlooked, is described. A general agreement is shown to exist between the stomachs of omnivorous and herbivorous forms and those of parasitic forms, but with certain modifications due to the physiological differences in the mode of obtaining nourishment. The mid- and hind-gut are only incidentally discussed.

"Facts and Theories on the Distribution of Scorpions in South Africa," by John Hewitt.

The only South African genus of the Scorpionini is a very primitive one; the South African members of the Ischnurini are also primitive on the whole. The advanced family Buthidae has its three most primitive genera in Africa, while the other South African members of the family belong to genera of wide distribution.

The prevalence of primitive types in South Africa seems definitely against the probability of a South African origin for the families concerned. Assuming that the region of greatest differentiation of a group is its centre of dispersal, then we must look to Eurasia as the immediate source of our scorpion fauna. But in most of the genera we find clear evidence of local evolution. These centres are different for different genera.

Lines of gradational series of forms are explained as phylogenetic series ranged along former routes of migration, the simplest and oldest forms having migrated furthest from the centre of origin, the most advanced and recent forms remaining near that centre. This hypothesis furnishes a rational explanation of the fact that the simplest member of the series is generally the most southern one.

"Note on Covariants and Invariants of Binary Quantics," by A. W. Veater.

"Note on Differential Invariants of the Group of Homographic Transformation of a Plane and of certain Sub-groups," by A. W. Veater (communicated by Prof. L. Crawford).

Wm. A. Jolly,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 20, 1924, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. Ogg, was in the Chair.

Business :—

The Minutes of last Meeting were confirmed.

The following were elected Members of the Society :—Dr. L. P. Bosman, B.A., B.Sc., Ph.D. ; Dr. L. Mirvish, M.A., M.B., Ch.B., and Professor G. A. Watermeyer.

Dr. Adrianus Pijper, M.D. (Leyden), L.M.S.S.A. (London), was nominated to membership.

Demonstrations :—

" Some South African Heteropterous Hemiptera showing Mimicry and Protective Coloration," by Dr. A. J. Hesse, Ph.D.

The study of mimicry has been chiefly developed in connection with Lepidoptera and Orthoptera. The Hemiptera (bugs) have been rather neglected from this point of view. This demonstration shows that there are many remarkable cases of mimicry to be observed in the Hemiptera. The demonstration dealt with (*a*) Cases of Protective Coloration of simple and complex type ; (*b*) True Mimicry, demonstrated, suggested or probable, and suggestive but disputed.

" The Louse of the Sea Elephant (*Macrorhinus leoninus*)," by Mr. R. F. Lawrence, M.A.

This louse (*Lepidophthirus macrorhini*), was found in very large numbers embedded in the skin of the elephant-seal, mostly on the head and snout. The species is distinguishable from all other Anopleura found on this group of mammals by the large scale-like hairs situated on the central portion of the dorsal surface of the abdomen. It is presumed that these hairs retain a film of air on the surface of the body while the host is submerged, as they only occur on the same side as the stigmatic openings and not elsewhere. Many of the large spines with which the body is well provided are bent to point posteriorly so as to offer less resistance to the entry of the head and thorax when feeding. These lice transferred themselves readily to a human host and in two cases succeeded in penetrating the skin and making their way under it for a short distance. The skin of the true host was in a very poor condition and in certain parts of it most of the hair had been lost.

Communications :—

" A Bibliographic List of pre-Stormberg Karoo Reptilia with a Table of Horizons," by S. H. Haughton.

This list contains references to the chief literature dealing with each of the species of pre-Stormberg Karoo Reptilia. The Stormberg fauna is

omitted since full references were given in the author's paper on the fossils from that series (Ann. S. Af. Mus., XII, 1924). It has been felt that such a list may be of assistance to those working at this most interesting assemblage of forms. The number of genera and species has of recent years increased rapidly and the descriptions have appeared in a number of scientific periodicals. To gather together this literature is the first necessary step in making a survey of the fauna.

The types are distributed among various collections in and outside South Africa. Some of them are fragmentary and can throw little light upon the larger questions of classification and development; a few are probably unidentifiable and must remain as tantalising curiosities of nomenclature. Of the well-defined forms much still remains to be done in the way of study and description in order that details may be added to the outline picture that is being gradually drawn.

"On the Periodicity of Rainfall," by G. W. Cox (communicated by Dr. C. M. Stewart).

A cursory inspection of any table of annual rainfall values discloses irregularities which suggest the results of pure chance. A vital question in long-range weather forecasting, implying as it does a knowledge of the laws governing the sequence of weather phenomena, is whether the values of data follow any law of succession separable from the law of chance. This paper contains an inquiry as to the existence of any cycle in rainfall.

Wm. A. Jolly,
Hon. General Secretary.

Annual Meeting.

The Annual Meeting was held on Wednesday, September 24, 1924, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. Ogg, was in the Chair.

Business:—

The following candidates were elected Fellows of the Society:—Charles Kimberlin Brain, M.A. (Ohio), M.Sc., D.Sc. (Birmingham), proposed by B. de St. Jean van der Riet, J. T. Morrison, R. Marloth, and C. P. Lounsbury; John William Cormack Gunn, M.A., M.B., Ch.B. (Edin.), proposed by J. C. Beattie, J. D. F. Gilchrist, H. Bohle, and G. W. Robertson; Basil Ferdinand Jamieson Schönland, B.A. (Cape), M.A., Ph.D. (Cantab.), O.B.E., proposed by J. C. Beattie, J. D. F. Gilchrist, H. Bohle, G. W. Robertson, and Alexander Brown; John

SMEATH THOMAS, D.Sc. (Liverpool), F.I.C., proposed by B. DE ST. JEAN VAN DER RIET, J. T. MORRISON, J. D. F. GILCHRIST, H. BOHLE, and ALEXANDER BROWN; PAUL ANDRIES VAN DER BYL, M.A., D.Sc.(Cape), proposed by J. T. MORRISON, B. DE ST. JEAN VAN DER RIET, R. MARLOTH, and C. P. LOUNSBURY.

WM. A. JOLLY,
Hon. General Secretary.

ORDINARY MEETING.

An Ordinary General Meeting of the Society was held on Wednesday, October 15, 1924, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. OGG, was in the Chair.

Business :—

The Minutes of the last Ordinary Meeting were confirmed.

Dr. ADRIANUS PIJPER, M.D. (Leyden), L.M.S.S.A. (London), was elected a Member.

The Hon. General Secretary announced the Council's recommendation for Officers and Council for 1925 as follows :—

Members of Council.—Sir CARRUTHERS BEATTIE, Dr. W. A. CALDECOTT, Dr. L. CRAWFORD, Dr. W. A. JOLLY, Dr. C. F. JURITZ, Mr. C. W. MALLY, Dr. A. OGG, Dr. ANNIE PORTER, Sir ARNOLD THEILER, Dr. J. SMEATH THOMAS, Dr. P. A. VAN DER BIJL, and Dr. A. YOUNG.

Officers.—President, Dr. A. OGG; Hon. Treasurer, Dr. L. CRAWFORD; Hon. General Secretary, Dr. W. A. JOLLY.

The following were received as Fellows :—Dr. J. W. C. GUNN, Dr. B. F. J. SCHÖNLAND, and Dr. J. SMEATH THOMAS.

Demonstration of—

"South African Species of Water-Net (*Hydrodictyon*)," by Miss E. L. STEPHENS, B.A., F.L.S.

Two species, *H. africanum* and *H. reticulatum*, were shown. The former is endemic to South Africa; the latter a new record for South Africa, though a cosmopolitan plant and found in North Africa. Both have so far been found only in temporary vleis in the Cape Division; their distinctive appearance makes them easily recognised, and records of their occurrence outside this small area would be welcomed.

Communications :—

"The Partial Pressures of Water and Sulphuric Acid Vapours over Concentrated Solutions of Sulphuric Acid at High Temperatures," by

JOHN SMEATH THOMAS and WILLIAM FRANCIS BARKER (Preliminary Note).

In a previous communication (J.C.S. 1923, 123, 3256) Thomas and Ramsay have described the measurement of the partial pressure of sulphuric acid vapour over concentrated solutions of sulphuric acid. The present investigation was undertaken with the object of extending the measurements so as to include the partial pressure of the water vapour. Since some doubt has arisen regarding the previous work these measurements of the sulphuric acid pressures were repeated.

The method adopted was the dynamical one of bubbling a carefully measured volume of air through acid at the required temperature and accurately determining the total quantity of vapour removed and also the amount of sulphuric acid contained in this vapour.

The apparatus was essentially the same as that previously used but several improvements were introduced. For example, the temperature was controlled by a thermometer immersed in the acid under investigation, and the arrangements for absorbing the acid vapour were greatly improved.

Up to the present only one concentration, 95 per cent., has been completely worked out. Between 180° and the boiling point the vapour pressures for this acid are given with considerable accuracy by the equations:

$$\log p\mathrm{H_2SO_4} = 7{\cdot}771 - \frac{3359}{\mathrm{T}}$$

$$\log p\mathrm{H_2O} = 9{\cdot}192 - \frac{3692}{\mathrm{T}}$$

$$\log p \text{ total} = 9{\cdot}1628 - \frac{3641}{\mathrm{T}}$$

Extrapolation of the total pressure curve to 760 mm. gave the value 304° for the boiling point of the acid, and this compares favourably with the experimentally determined value 303°—307°.

"On the Application of the Cathode Ray Oscillograph to the Study of Electrode Phenomena (Preliminary Note)," by E. NEWBERY.

The cathode ray oscillograph, supplemented with a thermionic valve, has been applied to the study of the single potential curves of a series of metallic cathodes in dilute sulphuric acid during make and break of the current through the cell.

Definite evidence of the existence of transfer resistance was obtained and its magnitude determined. The results show that the direct method of measuring overvoltage cannot be relied upon under any circumstances, and that the commutator method gives true values only when extrapolation to infinite speed is carried out.

All the phenomena observed are readily explainable on the hydride theory of overvoltage.

"The Pharmacological Action of *Acokanthera spectabilis*," by D. F. Morrison.

The pharmacological action of *Acokanthera spectabilis*, a tree indigenous to South Africa, on frogs and mammals is described in this paper. The main action is on the heart, and is similar to that of digitalis and of the other species of Acokanthera which have been investigated by previous authors. The hour dose for frogs, and the minimal lethal doses for cats, rabbits, guinea-pigs, and rats have been ascertained, and show that the plant possesses a high degree of toxicity. Attention is drawn to a relative immunity on the part of the rabbit.

The plant contains glucosides, but the nature of these has not yet been worked out.

"Note on Some Peninsula Plants," by M. R. Levyns.

In the course of some work on the flora of the Cape Peninsula a number of new or interesting plants have been recorded.

Species which are apparently new:

Albuca sp. (subgenus *Leptostyla*).
Anthericum sp. (subgenus *Trachyandra*).
Ficinia sp.
Crassula sp. (allied to *C. natans*).

Species which are not new but are recorded from the Cape Peninsula for the first time:

Lapeyrousia fistulosa Baker.
Psoralea uncinata E. & Z.
Psoralea glaucina Harv.
Mairea coriacea Bolus.

Rare or overlooked plants:

Euphorbia arceuthobioides Boiss.
Sutera antirrhinoides, Hiern.
Pellaea hastata Link.
Ceterach cordatum Desv.

In each case the distribution and a short account of the habit of the plant were given.

Wm. A. Jolly,
Hon. General Secretary.

Anniversary Meeting.

The Anniversary Meeting of the Society was held on Wednesday, March 18, 1925, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

Dr. S. H. Haughton was in the Chair.

The Report of the Honorary General Secretary was submitted and adopted.

The Report of the Honorary Treasurer was submitted and adopted.

The following were elected members of Council for the year 1925 :—

Sir Carruthers Beattie.	Dr. Annie Porter.
Dr. W. A. Caldecott.	Sir Arnold Theiler.
Dr. C. F. Juritz.	Dr. J. Smeath Thomas.
Mr. C. W. Mally.	Dr. P. A. van der Byl.

Dr. A. Young.

Dr. A. Ogg was elected President.
Dr. L. Crawford, Hon. Treasurer.
Dr. W. A. Jolly, Hon. General Secretary.

Ordinary Meeting.

An Ordinary Meeting was held after the Anniversary Meeting.

Dr. S. H. Haughton was in the Chair.

Business :—

The Minutes of the last Meeting were confirmed.

Mr. E. L. Gill, M.Sc., was nominated to membership.

Dr. S. H. Haughton moved the following recommendation to Council :—

That the sum of £350, earmarked in 1915 for the full-size reproduction in colour for distribution of the large slab of Bush-paintings from Zaamenkomst, Maclear, should be employed as follows :—

(1) For printing a small-size black-and-white (collotype or photogravure) copy of the work from a photograph—say, as a folding plate in the Transactions of the Society—in order to show the general proportions and relationships of the various figures comprising the scene ; and

(2) For issuing a full-size coloured print of a portion of the scene, in order to display the details of technique. This would have to be produced from a copy to be made by a reputable artist capable of faithful copying.

The balance, if any, of the sum of £350, should be devoted to anthropological research.

The motion was carried.

Communications :—

" Impressions of the Bird-Life of the Cape Peninsula " by E. L. Gill.

The first impression of all is that bird-life is scarce, though with obvious exceptions, such as the two common doves, the common white-eye and wagtail, and (unfortunately) the introduced starling. The scarcity as compared with bird-life in Europe is real, and is doubtless due ultimately to the dryness of the Cape summer ; but with a little experience the first impression is greatly modified. The good voices of many Cape birds (*e.g.* red-winged starling, bacbakiri, and one of the reed warblers) also strike a newly arrived ornithologist ; a surprising case is that of the fiskaal, a typical shrike, but with a pleasant warbling song. The few resident birds identical with British species, like the heron and water-hen, are birds of inland waters—the only habitat that is nearly alike in the two countries. The sun-birds and sugar-bird, giving a tropical air to the fauna, naturally strike a newcomer particularly.

" On the Form of the Electrical Response of Muscle," by William Adam Jolly.

The author discussed the occurrence of oscillatory electrical variations in the frog's gastrocnemius muscle in response to indirect stimulation by single induction shocks applied to the motor nerve.

Wm. A. Jolly,
Hon. General Secretary.

Report of the Hon. General Secretary for 1924.

Seven Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the following papers were read :—

1. " Fast Cathode Rays," by B. F. J. Schönland.

2. " The Mineral Germanite and the Extraction of Germanium and Gallium therefrom," by J. Smeath Thomas and William Pugh.

3. " Freshwater and Subaerial Algae of Natal," by F. E. Fritsch and Florence Rich (communicated by Miss E. L. Stephens).

4. " The Long Bones of the South African Bushman," by Vincent Vermooten (communicated by Prof. M. R. Drennan).

5. " Note on the Heterosomata of Portuguese East Africa," by C. von Bonde.

6. " On Photographs of an Oar-fish (*Regalecus glesne*)," by K. H. Barnard.

7. " South African Spiders," by R. F. Lawrence.

8. "The Smaller South African Shells that harbour Cercariae," by F. G. Cawston.

9. "Contributions to our Knowledge of the Freshwater Algae of Africa. V: On a Deposit of Diatomaceous Earth from Ermelo, Transvaal," by F. E. Fritsch and Florence Rich (communicated by Miss E. L. Stephens).

10. "Secondary Growth in some Iridaceae—Preliminary Note," by R. S. Adamson.

11. "Note on Systems of Determinants with Sets of deleted Elements," by Sir Thomas Muir.

12. "Colour and Chemical Constitution. Part XIX: Organic Fluorescence," by James Moir.

13. "On a Skull and Partial Skeleton of *Mesosuchus Browni* Watson," by S. H. Haughton.

14. "A South African Life Table based on the European Male Population Census," by C. W. Kops (communicated by Prof. J. P. Dalton).

15. "The Spermatogenesis of *Locustana pardalina* (Walker) (the Brown Trek Locust)," by D. J. Malan and D. E. Malan.

16. "A new *Trichostrongylus* from South African Sheep," by H. O. Monnig.

17. "The Digestive Canal of Isopod Crustaceans," by K. H. Barnard.

18. "Facts and Theories on the Distribution of Scorpions in South Africa," by John Hewitt.

19. "Note on Covariants and Invariants of Binary Quantics," by A. W. Veater.

20. "Note on Differential Invariants of the Group of Homographic Transformation of a Plane and of certain Sub-groups," by A. W. Veater (communicated by Prof. L. Crawford).

21. "Some South African Heteropterous Hemiptera showing Mimicry and Protective Coloration," by A. J. Hesse.

22. "The Louse of the Sea Elephant (*Macrorhinus leoninus*)," by R. F. Lawrence.

23. "A Bibliographic List of pre-Stormberg Karoo Reptilia with a Table of Horizons," by S. H. Haughton.

24. "On the Periodicity of Rainfall," by G. W. Cox (communicated by Dr. C. M. Stewart).

25. "South African Species of Water-net (*Hydrodictyon*)," by Miss E. L. Stephens.

26. "The Partial Pressures of Water and Sulphuric Acid Vapours over Concentrated Solutions of Sulphuric Acid at High Temperatures," by John Smeath Thomas and William Francis Barker (Preliminary Note).

27. "On the Application of the Cathode Ray Oscillograph to the Study of Electrode Phenomena (Preliminary Note)," by E. Newbery.

28. "The Pharmacological Action of *Acokanthera spectabilis*," by D. F. Morrison.

29. "Note on the Sum of the signed primary Minors of a Persymmetric Continuant," by Sir Thomas Muir.

Vol. XI, parts 3–4; and Vol. XII, parts 1–2, of the Society's Transactions have been issued during the year.

The following were elected Fellows of the Society in 1924:—Charles Kimberlin Brain, M.A.(Ohio), M.Sc., D.Sc.(Birmingham); John William Cormack Gunn, M.A., M.B., Ch.B. (Edin.); Basil Ferdinand Jamieson Schönland, B.A. (Cape), M.A., Ph.D. (Cantab.), O.B.E.; John Smeath Thomas, D.Sc. (Liverpool), F.I.C.; and Paul Andries van der Byl, M.A., D.Sc. (Cape).

The number of Honorary Fellows is as before: Fellows 59, Members 158.

The deaths since the 1924 Anniversary Meeting of Mr. W. G. Fairbridge, Sir Howard Gorges, and Mr. W. H. Taylor, Members, are recorded with regret.

Mr. R. D. Aitken, Mr. J. A. Alston, and Dr. A. Simpson Wells are resigning from the end of the year.

The names of two Members have been deleted from the list.

During the year 1924 the Council of the Royal Society of London kindly invited Fellows of the Society to attend meetings of the Royal Society of London without the necessity of introduction by a Fellow. The Society accepted the invitation and thanked the Royal Society of London.

The usual exchanges with the Library have taken place during the year. Forty-eight volumes have been bound, and it is proposed to carry out a further binding programme shortly.

Wm. A. Jolly,
Hon. General Secretary.

TREASURER'S ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1924.

TREASURER'S ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1924.

Revenue.

	£ s. d.	£ s. d.
To Subscriptions for 1924 :—		
Subscriptions collected for 1921	2 0 0	
,, ,, 1922	9 0 0	
,, ,, 1923	29 1 0	
,, ,, 1924	269 14 0	
,, ,, 1925	5 2 0	
,, collected in advance for 1924	5 11 0	
Outstanding Subscriptions at December 31, 1924	60 14 0	
	381 2 0	
Less : Outstanding Subscriptions at December 31, 1923, £61 ; Subscriptions collected in 1924 for 1925, £5, 2s.	66 2 0	
		315 0 0
,, Life Subscription		25 0 0
,, Entrance Fees		8 0 0
,, Government Grant, 1924–5		300 0 0
,, Interest received :—		
On Fixed Deposit, £500, at Standard Bank for one year at 4 per cent.	20 0 0	
On £408 New Union of South Africa 5 per cent. Stock	20 8 0	
On Money in Savings Bank Department of Standard Bank	12 18 5	
		53 6 5
,, Sale of Publications in 1924	49 10 1	
Plus : Amount due for Sale in 1924 ..	2 16 9	
	52 6 10	
Less : Purchase price of copies of Transactions, £5, 5s. : 1923 account paid in 1924, 15s.	6 0 0	
		46 6 10
		£747 13 3

Expenditure.

	£ s. d.	£ s. d.	£ s. d.
By Publications :—			
Cash Paid for Printing, etc., to Neill & Co.	242 0 6		
Cash Paid for Storage to Adlard & Son and West Newman	2 0 0		
Cost of Vol. XII., Part 1, and Vol. XII., Part 2	241 10 9		
		485 11 3	
Less : Receipts for extra reprints of Papers	8 18 5		
Amount due for extra reprints in 1924	9 8 7		
	18 7 0		
Amount received in 1924 for 1923 account	7 8 5		
		10 18 7	
			474 12 8
,, Compilation of International Catalogue of Scientific Papers			25 0 0
,, Clerical Assistance and Work in Library ..			65 0 0
,, Local Printing and Stationery			49 17 0
,, Postages and Petties			18 11 6
,, Binding : Accounts paid in 1924		11 5 0	
Amount owing for 1924		7 19 0	
		19 4 0	
Less : Amount on hand at end of 1923 ..		16 15 0	
			2 9 0
,, Bank Charges for Commissions, Ledger Fees, Fixed Deposit Stamps, etc.		2 14 3	
Less : Commissions paid by members ..		2 1 1	
			0 13 2
,, Hire of Rooms and Caretaker, 1924			6 6 0
,, Insurance in 1924 :—			
Library, etc., in University Library ..		0 10 6	
Stock held by Adlard & Son and West Newman		0 9 4	
			0 19 10
,, Cost of Conversazione in 1924 : Accounts paid		28 15 2	
Less : Balance brought forward from 1912 Conversazione		7 4 0	
			21 11 2
,, Profit in Year 1924			82 12 11
			£747 13 3

ASSETS AND LIABILITIES AT DECEMBER 31, 1924.

Assets.*	£	s.	d.
Money at Standard Bank on Fixed Deposit for one year at 4 per cent.	500	0	0
Money in Savings Bank Department of Standard Bank	498	10	1
Balance at Standard Bank as per Pass Book	225	14	4
Union of South Africa £408 5 per cent. Stock, 1929/39, reckoned at purchase price	400	0	0
Arrears of Subscriptions, as in Statement for 1923, £61; less £40, 1s. paid in 1924 and £8 struck off as irrecoverable	12	19	0
Arrears of Subscriptions for 1924, £51, 15s., less £4 struck off as irrecoverable	47	15	0
Amount due for Sale of Publications	2	16	9
Amount due for extra reprints of Papers	9	8	7
	£1697	3	9

Liabilities.	£	s.	d.	£	s.	d.
Subscriptions received in 1924 for 1925				5	2	0
Publications: Cost of Vol. XII., Parts 1 and 2, issued 1924				241	10	9
Earmarked for Expense of Publishing, as a part of the Transactions, a Reproduction of a Bushman Painting (Council Minutes, May 12, 1915), a sum not exceeding				350	0	0
Account for Binding in 1924				7	19	0
Excess of Assets over Liabilities:—						
Amount at December 31, 1923	£1009	19	1			
Add Profit in year 1924	82	12	11			
				1092	12	0
				£1697	3	9

* Exclusive of value of Library and Publications of the Society held in Stock.

Entrance Fees and Life Subscriptions Fund.

	£	s.	d.		£	s.	d.
Amount of Fund at January 1, 1924	310	0	0	Amount of Fund at December 31, 1924	343	0	0
Life Subscription received in 1924	25	0	0				
Entrance Fees received in 1924	8	0	0				
	£343	0	0		£343	0	0

We hereby certify that we have examined the above accounts of Revenue and Expenditure and of Assets and Liabilities, with the Books, Vouchers, and other documents relating thereto, and that in our opinion these accounts set forth a correct statement of the affairs of the Society.

W. N. ROSEVEARE,
B. F. J. SCHÖNLAND.

February 19, 1925.

An Ordinary Meeting of the Society was held on Wednesday, April 15, 1925, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

Dr. ANDREW YOUNG, Vice-President, was in the Chair.

Business :—

The Minutes of the last Meeting were confirmed.

Mr. E. L. GILL, M.Sc., was elected to membership.

The Hon. General Secretary announced that the President has nominated as Vice-Presidents for 1925 Sir ARNOLD THEILER and Dr. ANDREW YOUNG.

Communications :—

" Notes on Solar Parallax," by H. SPENCER JONES (communicated by Dr. J. K. E. HALM).

The importance of a reliable determination of this constant for establishing a base-line on which our knowledge of the dimensions of the visible universe is founded was pointed out, and the different methods of its determination were dwelt upon. These may be divided into three classes :—

(1) The observation of the apparent displacements of a planet like Mars or Eros against one or more stars viewed from two points differently situated in relation to the centre of the Earth ;

(2) Determinations of the orbital velocity of the Earth compared with the velocity of light by either the effect of the aberration of light on the positions of the stars or the displacements of the Fraunhofer lines in the spectrum of a star observed at diametrically opposite points of the Earth's orbit ;

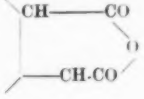
(3) Observations of occultations of stars by the Moon from which the perturbing influence of the Sun on the Moon's orbit known as the " parallactic inequality " can be ascertained.

It was shown that the best determinations of the solar parallax from these three independent methods lead to almost identical results, viz. 8″·805 with a probable error +0″·002.

" Some Observations on Aconitine," by LOUIS P. BOSMAN.

Aconitine ($C_{34}H_{47}NO_{11}$) on oxidation yields Oxonitine $C_{24}H_{31}NO_9$. It is known to contain three (CH_3O) groups, one (CH_3CO) group, one (C_6H_5CO) group, and one $N.CH_3$ group. At present the interest is centred around the fate of the other portion of the aconitine molecule.

The acetone extract yields a substance which, after repeated recrystallisations from alcohol, crystallises in prisms. M.P. 260°. M.W. 148 gives fluorescence reaction and other reactions which lead to suspicion of its being an inner anhydride of a dicarboxylic acid.



The difficulty of locating and isolating this substance has now more or less been overcome, and more is being prepared, and a further report will be submitted later.

WM. A. JOLLY,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 20, 1925, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

Dr. A. YOUNG, Vice-President, was in the Chair.

Business :—

The Minutes of last Meeting were confirmed.

The Hon. General Secretary announced that the following are candidates for Fellowship in 1925 :—

HENRY HAMILTON GREEN, D.Sc., F.C.S., proposed by I. B. POLE EVANS, E. PERCY PHILLIPS, ARTHUR W. ROGERS, and PERCY A. WAGNER ; HAROLD SPENCER JONES, M.A., F.R.A.S., proposed by ALEXANDER BROWN, A. W. ROBERTS, J. HALM, and Sir THOMAS MUIR ; HENRY HOWARD PAINE, M.A. B.Sc., proposed by Sir CARRUTHERS BEATTIE, ALEXANDER BROWN, J. T. MORRISON, and J. D. F. GILCHRIST.

Exhibit :—

Dr. S. H. HAUGHTON exhibited " Tracks of Animals preserved in the Ecca Shales of the Cape Province."

The specimens are from two localities in the Ecca Beds, one in the Zak River area, Calvinia, and the other from the cutting (Ecca Pass) on the road from Grahamston to Fort Beaufort, localities separated by a distance of 350 miles. The tracks are very well defined, and there are several forms common to the two localities.

The tracks are both invertebrate and vertebrate. The former include numerous crustacean footprints and the trails of more than one kind of worm. The vertebrate tracks consist in part of small groups of four-toed so-called " amphibian " prints, which lack a heel-pad, and which suggest that the feet were used for progression over very short distances of a few steps ; in part, doubtfully of oval impressions with a finely corrugated surface, as if due to the impress of a skin-covered " hoof-like " foot ; and in part of a series of peculiar parallel sinuous lines. No similar occurrence to the last has been found in literature ; and the suggestion is made that they are markings made by ventral spines of a fish armed after the fashion of the carboniferous and permian *Acanthodes*.

The discovery of such tracks opens up the possibility of finding actual remains of the animals responsible for them in the fine-grained Ecca Shales.

Communications :—

"Notes on the Habits and Life-Histories of Certain Little-known Anura, with Descriptions of the Tadpoles," by J. H. POWER.

The habits and metamorphosis, etc., of *Cassina Senegalensis*, *Phrynomantis bifasciata*, and *Bufo carens*, collected at Lobatsi, are described and the forms figured. The tadpole of *Cassina* was observed to devour mosquito eggs.

"Some Additions to the Knowledge of *Procolophon*, *Lystrosaurus*, *Noteosuchus*, and *Cistecephalus*," by F. VON HUENE (communicated by Dr. S. H. HAUGHTON).

A specimen in the Albany Museum shows an impression of the skin surrounding the parietal foramen of *Procolophon*. The skin surface carried small polygonal pits bounded by thick meandering walls, and did not cover the large parietal foramen, which is therefore considered to have contained a functional organ.

The skull of *Lystrosaurus* is shown to contain a transverse bone (ectopterygoid) in the same position as in *Dicynodon*. The detailed relationships of the bones surrounding the choanae are also traced.

Certain points in the structure of *Noteosuchus* are emphasised; and reasons are given for believing the small animal which is preserved alongside the type of *Noteosuchus* to be a very young *Cistecephalus*.

"Report on a Collection of Crustacea from Portuguese East Africa," by K. H. BARNARD.

The present collection contains 57 species, of which 14 have been previously recorded. Together with the author's collections made in 1912 for the South African Museum, the total number of species now known from this region is 211. This number is only about one-quarter of the number of species recorded from South Africa south of lat. 27° S., and evidently represents but a small part of the real fauna. The results of the survey are valuable in showing that there is still much to be done, especially in the deeper waters, in this region. The capture of a crayfish of the genus *Palinustus*, hitherto known only from the West Indies, and of three Indo-Pacific forms not reported since their discovery by the *Challenger*, are the most striking results. Two new varieties and two new species are described in the paper.

"New and Noteworthy South African Charophyta," by JAMES GROVES and EDITH L. STEPHENS.

Little attention has been paid to the South African Charophyta since the publication in 1867 of Braun's "Die Characeen Afrikas." Recent

collecting has shown that South Africa is rich in endemic types belonging to the group, some of them of outstanding beauty and interest, and this paper describes, with illustrative plates, six of these new species. Notes are also given on six other species which are new records for South Africa or otherwise of special interest.

"Contributions to our Knowledge of the Freshwater Algae of Africa. No. 6: Some Freshwater Algae from Stellenbosch," by W. J. HODGETTS (communicated by Miss EDITH L. STEPHENS).

The algae dealt with in this paper were collected by Miss Duthie of the University of Stellenbosch. 184 species are recorded, and 9 species, 8 varieties, and several forms are described as new and figured. The most striking feature of the collection is the relatively large number (53) of species of Desmids, a group which has been found to be rather scantily represented in collections from other parts of South Africa.

"Some Observations of the Radulae of Freshwater Mollusca," by F. G. CAWSTON.

The author describes and figures the cones and the cusp-formation in the radulae of those freshwater mollusca which serve as intermediate hosts for trematoda in South Africa. Examples are described at various stages of growth and in different parts of the same radula.

WM. A. JOLLY,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 17, 1925, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

Dr. C. F. JURITZ was in the Chair.

Business:—

The Minutes of the last Meeting were confirmed.

Communications:—

"A Statistical Enquiry into the Population Problem in South Africa," by A. W. ROBERTS.

After setting out the mathematical theories for the variation in the population of any state where the conditions governing the growth of the population may be considered fairly uniform, the paper proceeded to deal with the populations of the various distinctive parts of South Africa, enumerations dealing with Whites being kept separate from those dealing with Natives.

Cape Colony :—

Population data stretching over two hundred years are used. The earlier enumerations are more or less estimates : those taken subsequent to 1875 are very exact. When these figures are rigorously dealt with it is found that the rate of increase of the White population in the Cape Colony is subject to a cyclical variation completed in 170 years. The rate of increase has been decreasing during the past twenty years.

Natal :—

Exact statistics here go back to 1860. Again there is evidence of cyclical variation. The rate of increase has been steadily decreasing during the past ten or fifteen years.

The Orange Free State :—

Population figures in the Free State go back to 1855. There is distinct evidence of secular change in rate. This rate is, like that of all the other provinces, decreasing.

The Transvaal :—

There are statistics available, irregularly, since 1855. The rate of increase is on a distinct downward grade.

Combined results :—

The official enumerations since 1904 indicate that the rate of increase is less than 2 per cent., and is slowly decreasing.

Native Results :—

Early enumerations of the Native population are not available. Those taken in recent years indicate a declining rate in every instance but one, Zululand. The rate is increasing here but very slowly.

The decrease in rate of the Colonial Natives is such as to give grounds for alarm.

"A Note on Azotobacter in some South African Soils," by W. J. Copenhagen.

The author examined samples of soil from a number of localities in the Cape Province, and records the hydrogen-ion concentration, moisture, amount of organic matter, N. per gram, characters of cultures and N. fixed per culture.

"Colour and Chemical Constitution. Part XX : Some Residual Problems," by James Moir.

Wm. A. Jolly,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, July 15, 1925, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

Dr. A. YOUNG, Vice-President, was in the Chair.

Business :—

The Minutes of the last Meeting were confirmed.

The following were nominated for membership :—

Mr. C. W. KOPS, B.A., A.I.A., proposed by Professor J. P. DALTON, seconded by Professor L. CRAWFORD ; Miss S. GARABEDIAN, B.A., proposed by the Hon. General Secretary, seconded by Professor L. CRAWFORD ; Mr. V. WAGER, B.Sc., proposed by Dr. D. J. MALAN, seconded by the Hon. General Secretary ; Professor R. A. DART, M.Sc., M.B.Ch.M., proposed by Professor M. R. DRENNAN, seconded by Professor L. CRAWFORD.

It was decided to entertain the scientific members of the Meteor Oceanographic Expedition to lunch.

Communications :—

" Note on South African Rhyncophora," by A. J. HESSE.

The author discussed some specific variations in the polymorphic genus *Brachycerus*. There are 270 species of this genus in South Africa. Their chief enemies are secretary birds, bustards, and avicularid spiders. The eggs, which are rarely found, are deposited two or three at a time. Some larvae are used as food by natives. Certain larval secretions form a native remedy for toothache. The adult insects are used by the Zulus as pendants for necklaces. It is possible to show a gradation of characters from species to species in certain groups. The author discussed the question whether the individual variations are truly specific.

" The Molluscan Hosts of South African Trematoda," by F. G. CAWSTON.

Cercariae have been isolated from at least eighteen species of freshwater mollusca in South Africa, including the three genera of Ancylidae.

" Note on the Arachnida of South-West Africa," by R. F. LAWRENCE.

Some new Arachnids from South-West Africa were discussed. The relation of the Pseudoscorpions to the other groups of Arachnida was first touched upon and, in illustration, a new species of *Garypus* from Sesfontein, South-West Africa, was exhibited. This species was an exceptionally large one, measuring 7 mm. in length, found under thin layers of weathering limestone. The comparative abundance of these Arachnids in South-West Africa was commented on, the author having found from 200–300 small adult specimens under a single stone after heavy rains. Living together with Pseudoscorpions in these narrow crevices were found the flattened scorpion *Hadogenes*, a Pedipalp, *Damon*, and an *Argas* species of flattened tick supposed to be parasitic on a small parrot *Agapornis roseicollis*.

The degeneration of the eyes owing to disuse in spiders living under stones was mentioned, a striking example being a new species of binocular spider—*Diploglena*, closely related to the genus *Nops*, which only occurs on the islands off the mainland of Brazil and Venezuela.

WM. A. JOLLY,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 19, 1925, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. OGG, was in the Chair.

Business :—

The Minutes of last Meeting were confirmed.

Mr. J. W. PONT, M.Sc., proposed by Professor POTTS, seconded by the Hon. General Secretary, was nominated for membership.

The following were elected Members of the Society :—

Mr. C. W. KOPS, B.A., A.I.A.; Miss S. GARABEDIAN, B.A.; Mr. V. WAGER, B.Sc.; and Professor R. A. DART, M.Sc., M.B.Ch.M.

Communications :—

"On Some New Mollusca from Tertiary Beds in the West of the Cape Province," by S. H. HAUGHTON.

The following new mollusca are described from a deposit at Doornbaai, on the Van Rhynsdorp coast, south of the Olifants River mouth: *Mytilus tomlini*, sp. nov. *Donax* (*Iphigenia*) *rogersi* sp. nov. and *Chamelea Krigei* sp. nov. The beds from which the shells were obtained average about 10 feet in thickness and form the upper portion of marine cliffs, which attain a height of 50 to 60 feet above sea-level. The shells were collected by Mr. A. V. Krige, M.Sc.

"On the Anatomy of Some Shrubby Iridaceae," by R. S. ADAMSON.

In the S.W. Cape region there are five species of the Iridaceae which form woody stems with secondary growth. The main features of the structure of these plants were described.

While the general type of secondary growth is the same as that occurring in other monocotyledons with secondary thickening, there are many differences in detail. The secondary tissues are much more compact and in some of the plants show a definite arrangement into concentric growth zones.

"The Breeding Habits and Life-Histories of some of the Transvaal Amphibia," by VINCENT A. WAGER.

In this paper the author describes the life-histories and habits of two species of Transvaal batrachia, *Chiromantis xerampelina* and *Rappia marmorata*; both are tree-living, the terminal phalanges provided with adhesive discs. In the first-named species the eggs are laid in the form of a large white glutinous mass on branches overhanging water. The tadpoles drop from the egg-mass into the water where they complete their metamorphosis. The fore-limbs, before breaking through the operculum, are already provided with phalangeal discs. The tadpole does not increase in size during metamorphosis and when the tail disappears the young frog leaves the water for an arboreal existence.

In *Rappia marmorata* the eggs are laid in a jelly-like mass under water. A peculiarity of the tadpole is the absence of horny jaws, comb-teeth, or papillae of the mouth, which bears a superficial resemblance to that of the tadpole of *Xenopus laevis*, but from which it can be readily distinguished by the absence of the two tentacles at the sides of the mouth. From this it is concluded that the tadpole feeds on micro-organisms in water drawn through the unusually large spiracle, and this is borne out by an examination of the intestinal contents, which includes amongst other organisms Euglena, Volvox, and a few minute annulates. When the fore-limbs break through the gill chamber the apertures thus caused are used as accessory spiracular openings, the spiracle itself falling into disuse.

(The genus *Rappia* itself has as yet not been satisfactorily systematised and there is much doubt as to the specific values of the various known forms. Before the life-history and habits of any species is described, a thorough revision of the genus is necessary.)

"Cathode Ray Scattering," by B. F. J. Schönland.

Preliminary measurements of the scattering of fast cathode rays through 90° have been made under conditions which ensure "single" scattering. Values for the nuclear charges of gold and aluminium are derived from these results which lie within 12 per cent. (the experimental error) of the true values. They support the addition of the relativity correction to the orbit of a β particle, this correction having the high value of 2·40 in the present case.

"Marriage and Mortality Rates of the Population of the Union of South Africa according to the Conjugal Condition of the Population," by C. W. Kops.

The paper is a preliminary investigation into the marriage rates among widowed persons and never-married persons, and the death rates among widowed, never-married, and married persons. It is shown that widowed persons have a higher marriage rate than the never married, and explanations are suggested. The lower mortality of the married persons compared with that of the never married (except for the early years of marriage in

the case of females) is also indicated, and again explanations are offered. It is pointed out that this is only a preliminary investigation and not intended to serve for purposes of valuation of annuity and other benefits.

Wm. A. Jolly,
Hon. General Secretary.

Annual Meeting.

The Annual Meeting of the Society was held on Wednesday, September 30, 1925, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. Ogg, was in the Chair.

The following candidates were elected Fellows of the Society :—

Henry Hamilton Green, D.Sc., F.C.S.; Harold Spencer Jones, M.A., F.R.A.S.; Henry Howard Paine, M.A., B.Sc.

Ordinary Meeting.

An Ordinary Meeting was held after the Annual Meeting.

The President was in the Chair.

Business :—

The Minutes of the last Ordinary Meeting were confirmed.

The President gave notice in terms of Statutes Chapter VI, 1, of the election next March of the Council, President, and Officers for 1926.

Mr. J. W. Pont, M.Sc., was elected a Member of the Society.

Professor C. E. B. Bremekamp, proposed by Dr. A. J. T. Janse, seconded by the Hon. Treasurer, was nominated for membership.

Communications :—

"Colour and Chemical Constitution. Part XXI: An Astronomical Orbit Theory of Colour with special reference to the Dicyclic Azo Dyes," by James Moir.

In the monocyclics colour is built up from one ring by adding a hapton; in the dicyclics colour is built down by bending the chain. The mathematical theory in the paper does not supplant the author's earlier factorial theory, but endeavours to give it a physical basis.

"Note on Witchcraft in Europe: The Case of Anne Boleyn," by C. Pijper.

The motive for the execution is considered to have been the belief that Anne Boleyn was an adherent of the witch-cult. The author bases his study on the work of M. A. Murray.

"The Preparation of Umbelliferone," by ERNEST GEORGE.

"Some Phthalein Analogues," by ERNEST GEORGE (communicated by Dr. JAMES MOIR).

"The Bryophyta of South Africa," by T. R. SIM.

The communication contains descriptions and plates of Sphaerocarpales, Marchantiales, Jungermanniales, Anthocerotales, Sphagnales, Andreaeales, Polytrichales, and Bryales.

WM. A. JOLLY,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, October 21, 1925, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. OGG, was in the Chair.

Business :—

The Minutes of the previous Meeting were confirmed.

Professor C. E. B. BREMEKAMP was elected to membership.

Communications :—

"Note on the Decrease in Acidity during the Ripening of Grapes," by P. R. v.d. R. COPEMAN.

In the ripening of grapes the most important changes occur in the sugar and acid content of the juice. The acidity, as determined by titration, decreases during the period of ripening, and when the logarithm of the acidity is plotted against the time a straight line is obtained. The observations include determinations of acidity made in 1923 and 1925. The changes in acidity may be expressed by the curve $\log c = a - bt$ and the values of "a" and "b" calculated from the experimental data.

Therefore $c = ke^{bt}$ and $dc/dt = -bc$.

The concentration of acid, therefore, varies with the time, and the rate of decrease is proportional to the existing concentration. The acidity at any given time depends upon the variety of grape. The rate of decrease of acidity, as measured by "b," is independent of the variety but is dependent upon some seasonal variation. The rate at which the grapes ripen during any given season is independent of the variety.

The curves, obtained from the data, agree well with the expression

$\log c = a - bt$, but at the end of the period tend to flatten out and at maturity the decrease in acidity becomes practically negligible.

"An Extension of Ceva's Theorem to Polygons of any Number of Sides," by ALEXANDER BROWN.

The extension of Ceva's Theorem here considered applies to a polygon of any number of sides, odd or even. For a polygon of $2m$ sides it gives $m-1$ relations, and for a polygon of $2m+1$ sides it gives m relations. From these, various special results already known can be derived as particular cases.

"The Hydrolytic Properties of Certain Amino-Acids," by LOUIS PIERRE BOSMAN.

Falk and Nielson (J. Amer. Chem. Soc., xxxiv, 1, 755, 1912) state that the amino-acids glycine, alanine, leucine, aspartic and glutamic, bring about the hydrolyses of esters such as methyl acetate, ethyl butyrate, and olive oil. It was found, however, that the actual hydrolyses cannot be attributed to the fact that these acids contain the amino-group. These authors omitted the consideration of the hydrogen-ion concentrations of the media in which the esters were being acted upon. These have been taken into account, and the conclusions arrived at point to the fact that the acidity of medium rather than the presence of the $-NH_2$ group is the cause of the hydrolyses.

"Note on the South African Marine Mussel, *Mytilus meridionalis*, Krauss (1848)," by D. B. SWART (communicated by Dr. C. VON BONDE).

The object of this paper is to clear the confusion that seems to have arisen with regard to the specific characters of the South African marine mussel. The author gives a description of the mussel, and verifies Krauss's findings and supplies additional evidence establishing *Mytilus meridionalis* beyond all doubt as a distinct species.

"I. On Instruments and Methods for Stereoscopic Surveying. II. The Optical Transformation of Projections and its Application to Mapping from Air Photographs. III. On some Conditions for the Accurate Vision of Stereoscopic Pictures," by H. G. FOURCADE.

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